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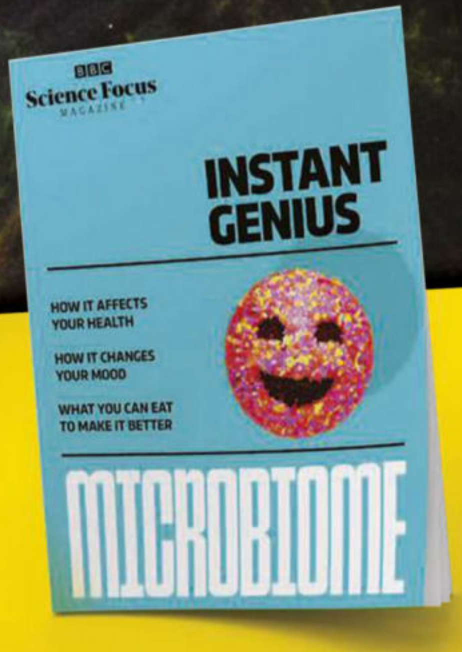

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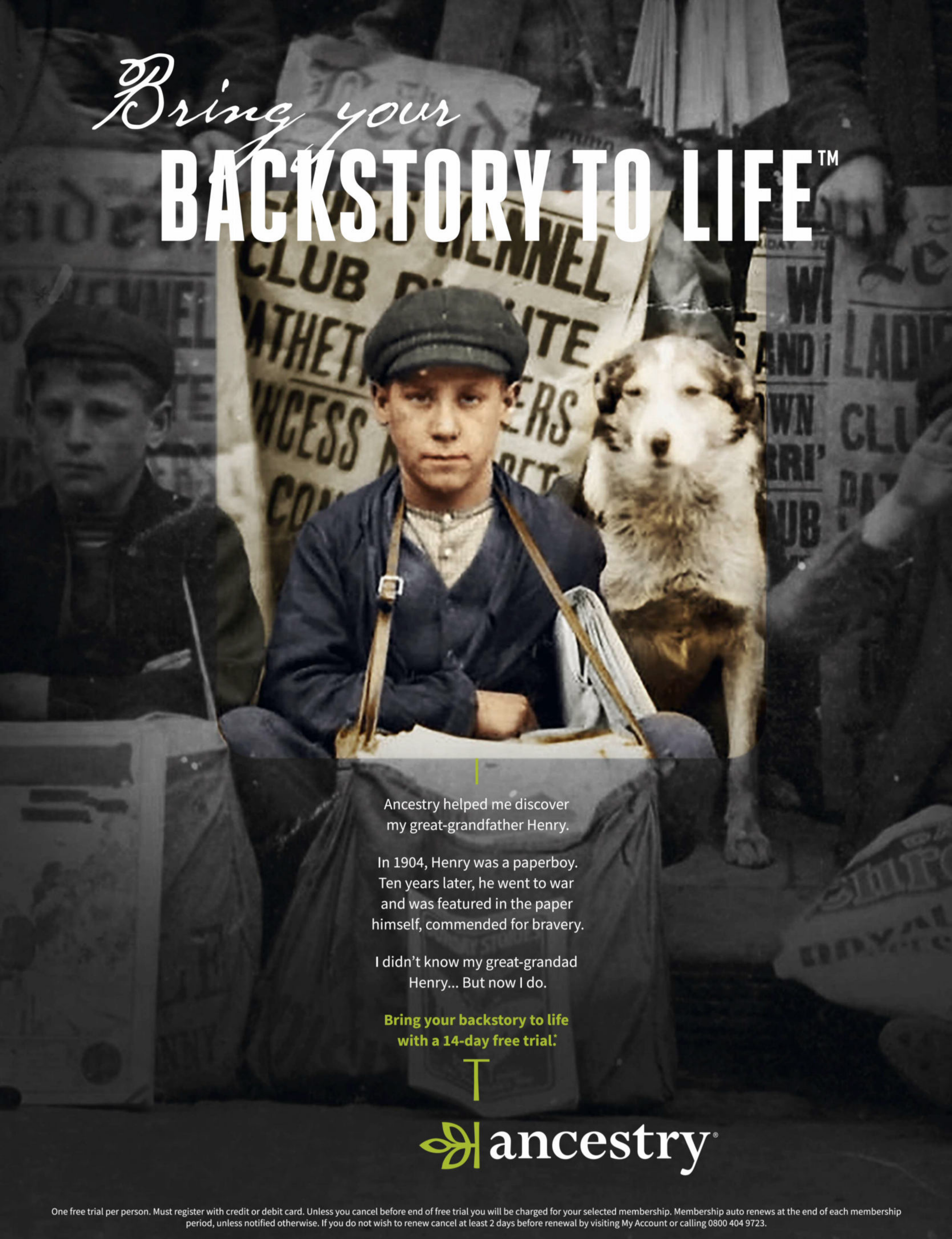

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FROM THE EDITOR

I'm sure you don't need me to tell you these are strange times. But I'm hoping that over the coming weeks and months, this magazine might be able to do some good.

First and foremost, we're here to answer your questions about the coronavirus. There's a lot of misinformation out there, so send your queries to **questions@sciencefocus.com**, and we'll get you answers. On p30, we talk to an expert from the London School of Hygiene and Tropical Medicine about why washing your hands is so effective at slowing the spread of COVID-19. Over on p32 we unpack the science behind herd immunity, and on p24 we ask a virologist whether the summer could loosen coronavirus's grip. Plus there's more in our *Q&A* section on p81.

Of course, there's more to life than this pandemic, so we've got a brilliant read on Hubble's past, present and future (p51), and also a detective story charting how DNA databases and ancestry websites are helping police around the world solve cold cases (p74).

In the meantime, if your kids are bored and you want to keep them occupied while sneaking in some science, head to **bit.ly/science_is_fun**. There you'll find 15 kitchen experiments that will help fill in some of the gaps while schools are closed.

And finally, we have a special three-month offer for new subscribers that just requires a one-off payment – a simple, no-strings way to get *BBC Science Focus* delivered direct to your door. Head to **buysubscriptions.com/SFspring3** to order online, or call 03330 162 138 and (quote code SPR3MPG, *BBC Science Focus*). Full T&Cs available online. Alternatively, turn to p80.

Daniel Bennett

Daniel Bennett, Editor

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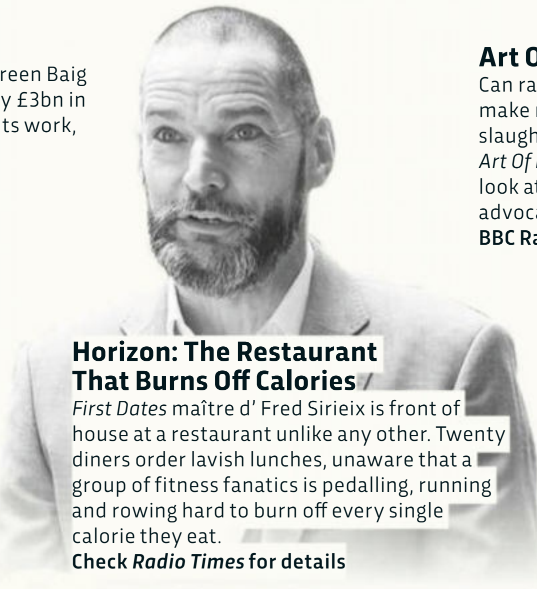
ON THE BBC THIS MONTH...

The Truth About Cosmetic Treatments

Dr Michael Mosley and journalist Mehreen Baig take a look at an industry worth nearly £3bn in this two part series. Do any treatments work, and even if they do at what cost?

Check *Radio Times* for details



Horizon: The Restaurant That Burns Off Calories

First Dates maître d' Fred Sirieix is front of house at a restaurant unlike any other. Twenty diners order lavish lunches, unaware that a group of fitness fanatics is pedalling, running and rowing hard to burn off every single calorie they eat.

Check *Radio Times* for details

Art Of Now: Raw Meat

Can raw meat be beautiful? Can we make real leather without killing? Can slaughter be replaced by science? The *Art Of Now* gets bloody in a unique look at meat, that isn't simply advocating veganism.

BBC Radio 4, 28 April, 11:30am

COVER: NASA/HUBBLE SPACE TELESCOPE THIS PAGE: GETTY IMAGES BBC X2

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DR ELIZABETH PEARSON

As the Hubble Space Telescope celebrates its 30th birthday, *Sky At Night Magazine*'s news editor reveals the telescope's hidden gems. → p42

COLIN BARRAS

Colin is a freelance science writer. In this issue, he finds out the best ways to reduce the carbon footprint of your diet. → p62

SALLY BLOOMFIELD

Can washing our hands really protect us against coronavirus? Sally Bloomfield, honorary professor at the London School of Hygiene and Tropical Medicine, explains the science of stopping the spread. → p30

JIM AL-KHALILI

Theoretical physicist and broadcaster Jim Al Khalili tells us his essential reading for physics fans. → p94

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CONTENTS

REGULARS

06 EYE OPENER
Incredible scientific images from around the world.

12 CONVERSATION
Your letters, emails, texts and tweets.

14 DISCOVERIES
All the month's biggest science news. In this issue: rat leg transplants; ghost ship washed up on Irish coast; coronavirus updates; ocean plastics smell like food to turtles; Heathrow airport expansion stopped, and much more.

30 REALITY CHECK
The science behind the headlines. This month: Does hand washing really prevent us from getting infected with coronavirus? What is herd immunity and can it help us fight coronavirus?

34 SUBSCRIBE TODAY!

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36 INNOVATIONS
The latest tech news and gadgetry.

71 MICHAEL MOSLEY
How to stay young by eating less.

72 ALEKS KROTOSKI
What an unexpected pandemic in *World Of Warcraft* can teach us about coronavirus.

81 Q&A
Our experts answer your questions. This month: Why does Bolognese sauce stain plastic containers? Can we bring back an extinct species?

90 BOOKSMART
Feast your eyes on our brand new section, and don't miss the launch of our new Science Focus Book Club!

96 NEXT MONTH
A sneak peek at what's in next month's *BBC Science Focus.*

96 CROSSWORD
In lockdown? Try our tricky cryptic crossword to get those brain cells working.

98 A SCIENTIST'S GUIDE TO LIFE
How to make the most of your (very long) solo runs.

26 DISCOVERIES

Follow a team of researchers as they explore a cave to find a new species of blind fish.

30 REALITY CHECK

How effective is hand washing at stopping the spread of infections like coronavirus?

62 EATING GREEN... THE DIRTY TRUTH
Is there a way for us to enjoy a varied diet perhaps with a little bit of meat and dairy – and still keep our carbon footprint low?

FEATURES

42 HUBBLE'S HIDDEN GEMS
Stunning images of the cosmos.

51 WHAT HUBBLE TAUGHT US
This special feature from our friends at *BBC Sky At Night* reveals how Hubble has transformed our knowledge of the Universe.

62 EATING GREEN... THE DIRTY TRUTH
Will printing carbon footprint information onto food packaging change our eating habits?

74 FAMILY TREE FORENSICS
Some people committed crimes years ago and thought they got away with their wrongdoings. But genetic genealogists can use DNA data from family history sites to track them down.

42

HUBBLE'S HIDDEN GEMS

90

BOOKSMART

NEW SECTION

Join our free, online book club, and discover five top physics books as chosen by Jim Al-Khalili.

72

COLUMN: ALEKS KROTOSKI

“SOME PEOPLE LIKE TO BE AGENTS OF CHAOS, SPREADING THE DISEASE ‘FOR THE LOLZ’ OR FOR RANSOM”

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EYE OPENER

Hang in there

VICTORIA, AUSTRALIA

Late in 2019, as the decade drew to a close, Australia experienced its hottest and driest summer in recorded history. This colony of grey-headed flying-foxes, or fruit bats, huddled together in an attempt to survive the relentless 42°C heat. They were dehydrated and suffocating.

Firefighters in Yarra Bend Park sprayed water onto the colonies in an attempt to cool them down. It's natural instinct for the bats to clump around trees, but by doing so, the danger to this vulnerable species increases. If one falls, the rest fall. And they further risk death from crushing.

It's not all bad news, though. Scientists at Western Sydney University have developed an early warning system, called The Flying-Fox Heat Stress Forecaster. By monitoring weather patterns, it's hoped authorities will have about 72 hours notice to allow life-saving measures to be put into place before a mass die-off event occurs.

DOUG GIMESY/NATUREPL.COM

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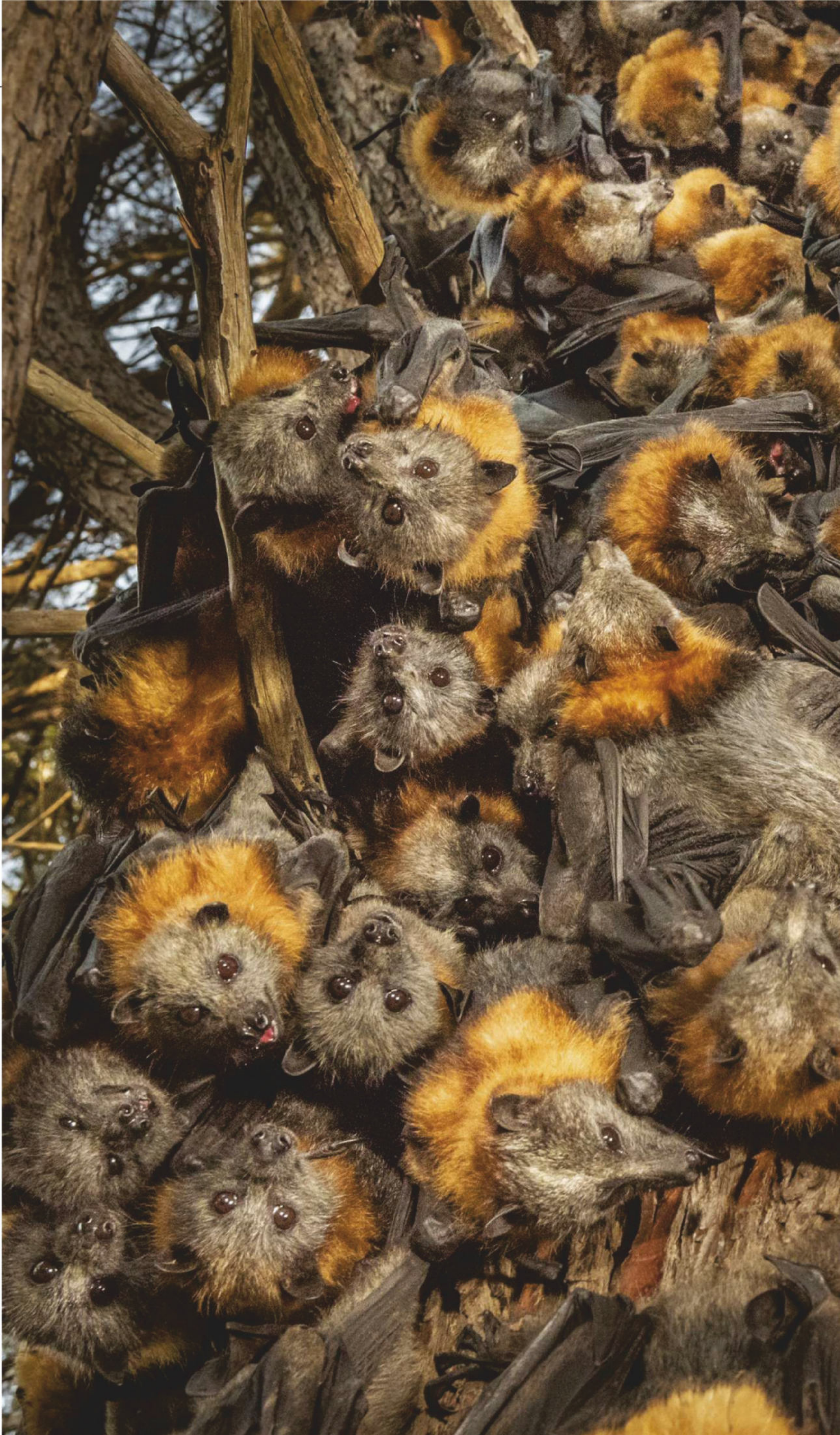

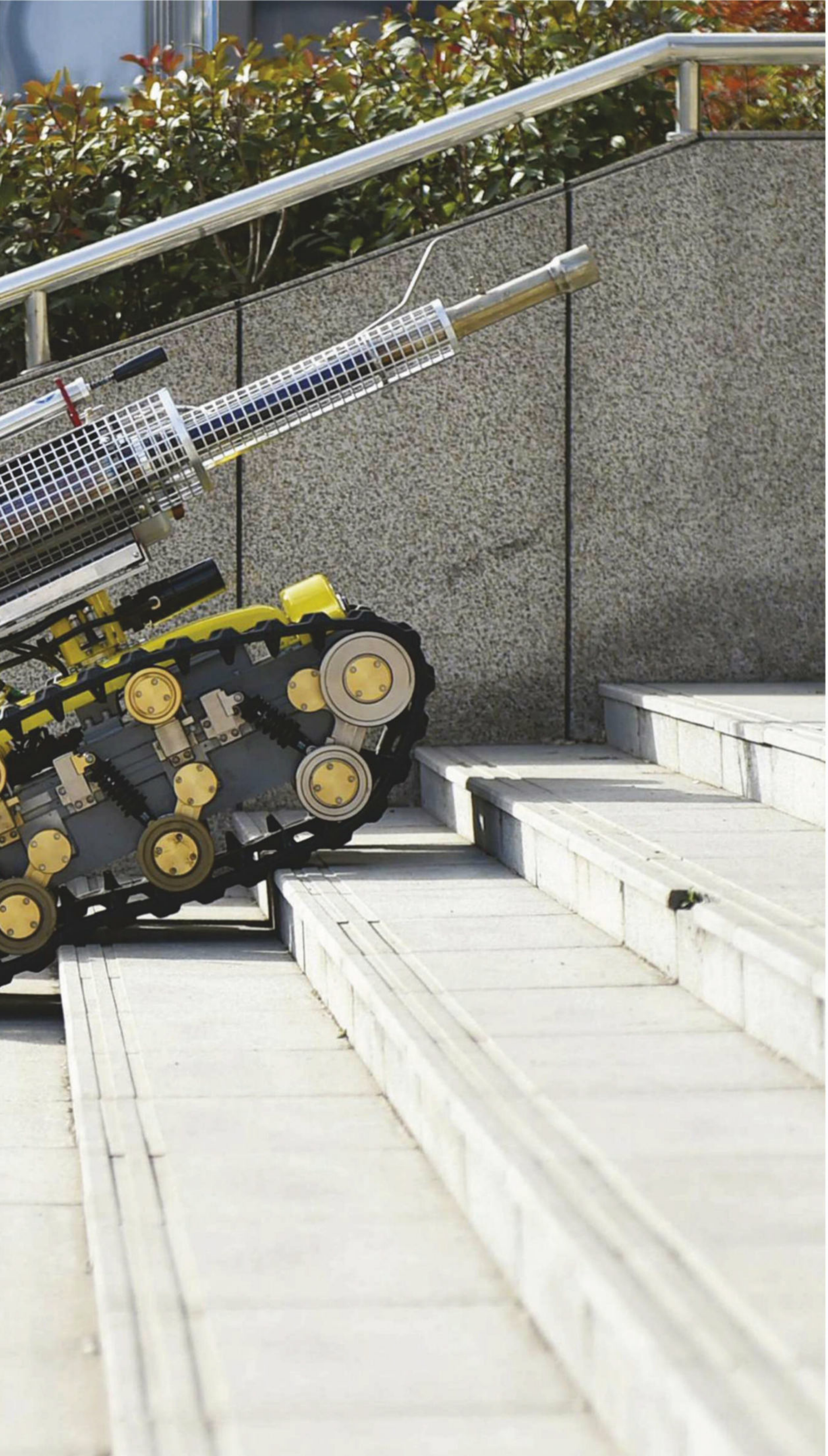

EYE OPENER

Corona bot

LUOYANG, CHINA

The sound of footsteps has been replaced by the whirring of gears in China. Technology supported the country's coronavirus crisis, with robots providing companionship for the quarantined and drones being used to deliver food and medicine.

Out on the streets, robots like this one are spraying disinfectant to kill microbes. "The disinfectants common in our households are alcohols, detergents and bleach, which work by destroying the proteins and lipids that bacteria and viruses are made of," explains Dr Adam Ostrowski, a molecular microbiologist. "Many industrial applications will use disinfectants in gas form, but given these robots work outside, it's unlikely they'll be spraying gas. It wouldn't be a detergent: they're too slippery and may cause people to slide and fall. I suspect it's some form of alcohol or bleach, which will remain in place for a while then evaporate, to keep people safe."

REUTERS

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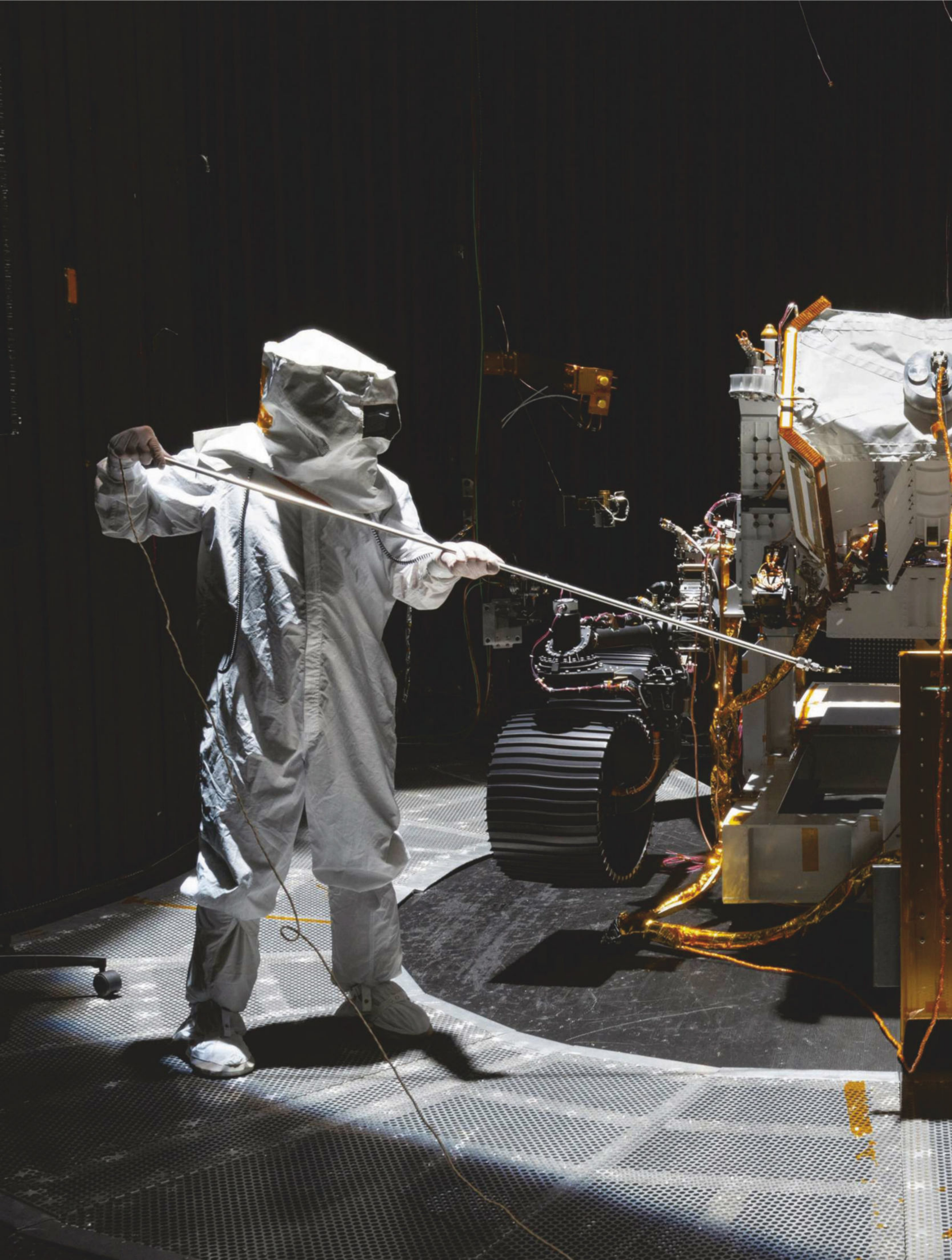

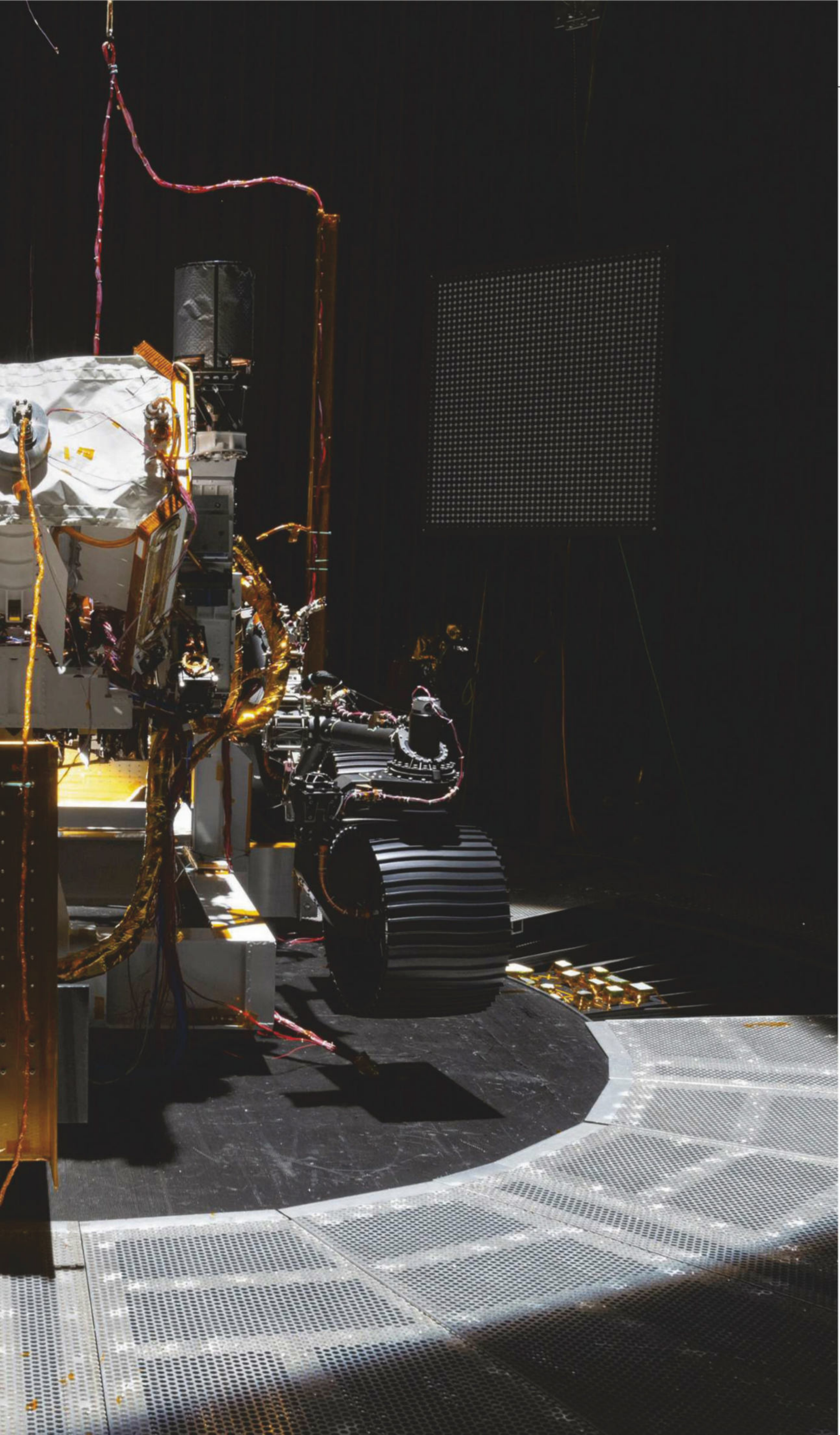

EYE OPENER

A light touch

CALIFORNIA, USA

An engineer uses a solar intensity probe to carefully measure the amount of artificial sunlight reaching different parts of NASA's Mars 2020 rover, at the Jet Propulsion Laboratory in California. Using this crucial data, scientists will be able to determine how this robotic scientist will interact with the Sun while on the Martian surface.

For the test, powerful xenon lamps were used to simulate the Sun, as the spectral output of xenon is similar to that of our star. The lamps were illuminated several floors below the craft, then bounced off a mirror at the top of the chamber onto the rover.

Based on the design of Curiosity, which landed on Mars more than seven years ago, the newly named Perseverance rover will carry new instruments, including a helicopter drone. The Mars Helicopter will hitch a ride in the rover's belly, then will be placed on the surface of the Red Planet to test the first-ever powered flight in the thin Martian air.

NASA/JPL

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CONVERSATION

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LETTER OF THE MONTH

To judge a book by its cover

I found Adam Rutherford's interview (February, p92) and podcast on science and racism interesting – I did not know there still existed people who attempt to use genetics to justify mistreatment of other human beings.

I realise all humans – probably all species with vision – react to appearances, at first. However, it is not difficult for us to move beyond appearances, nor is it to our detriment.

It is good to know science can debunk malicious, chauvinistic or reactionary beliefs. Too bad we can't legislate acceptance, love and compassion.

Brian Muldoon, Washington DC, *via email*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Kanto YU4 Powered, Wireless, Bookshelf Speaker System**. This all-in-one setup is all you need to play vinyl, stream audio, bring movies to life, and make gaming immersive. Versatile with big, detailed sound. **kantoaudio.com**

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That's a wrap on plastic

Very pleased to see that *BBC Science Focus* magazine is now mailing in recyclable paper envelopes instead of non-recyclable plastic film. Keep up the good work, and hopefully other publishers will follow suit!

Tony Manser, Ireland, *via email*

Thanks Tony! Since January 2020 all our monthly subscribers have received their copy of the magazine in paper wrapping. This is the same for our sister titles, such as *BBC Sky At Night* and *BBC History Magazine*. Across Immediate Media, our publisher, over 520,000 subscribers receive their monthly magazines mailed in paper, which means a huge reduction of more than 7.7 million pieces of plastic and a saving of around 43.3 tonnes of plastic a year.

We are totally committed to reducing our carbon footprint, and introducing more climate friendly products, and we will continue to drive this forward in 2020.

Daniel Bennett, Editor

Back at'choo

On p98 (January) you have Ron Eccles making the preposterous suggestion that a person with a cold should selfishly seek out hot, crowded conditions, such as cinemas, to 'make themselves feel better'. Does it make people feel better to bring misery to innocent bystanders?

Brian Bonner, *via email*

I was quite astounded by Ron Eccles' suggestion. In my opinion, anyone with a cold or health issue that is transmittable should stay indoors until they are better. Exceptions being back and forth to a doctor or to buy medicines. Not to enjoy oneself and spread the illness to others.

Brendan McDermott, *via email*

I take issue with Prof Eccles' advice on dealing with a common cold and hope that I am not sitting near him when he visits the cinema to cheer himself up.

Dr Kevin Privett, Cowbridge, *via email*

Common colds are infectious for at least seven days and adults get between two to five colds a year. Infants and schoolchildren get many more, up to 10 colds a year.

If adults were to avoid crowded places such as work, sports events, public transport, etc. and children were kept away from school in isolation for a week every single time they had a cold, the world would come to a stop.

Of course, with severe illnesses such as influenza and COVID-19, self-isolation is intended to slow the spread of infection and may be effective. But colds are so common, and we spend so much time in crowded places, that isolation to prevent colds just does not work.

Prof Ron Eccles, *former director of the Common Cold Centre*

"THE ACCIDENTAL PANDEMIC IN WORLD OF WARCRAFT PROVIDED AN INTERESTING PLACE TO WATCH HUMAN BEHAVIOUR THAT REFLECTS WHAT MAY HAPPEN WITH SOMETHING LIKE COVID-19"

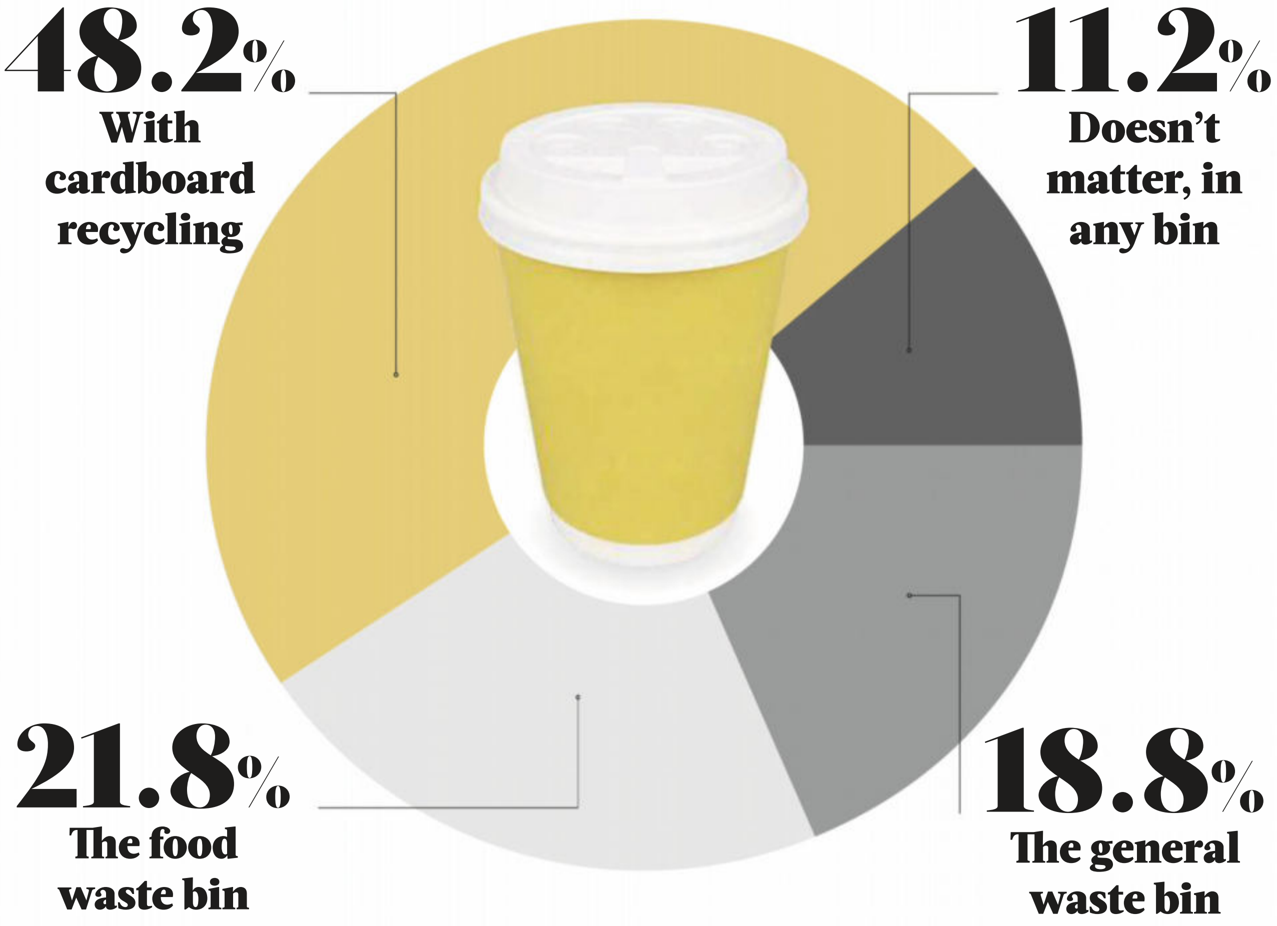
ALEKS KROTOSKI, P72

READERS' BUZZ

Your views on the burning science topics of the month

Last month, materials scientist Dr Mark Miodownik told us that biodegradable plastics should be put in the general waste bin, because most household recycling won't be at the right temperature for it to biodegrade. But did our Twitter followers agree?

WHERE DO YOU THROW AWAY YOUR BIODEGRADABLE CUP?



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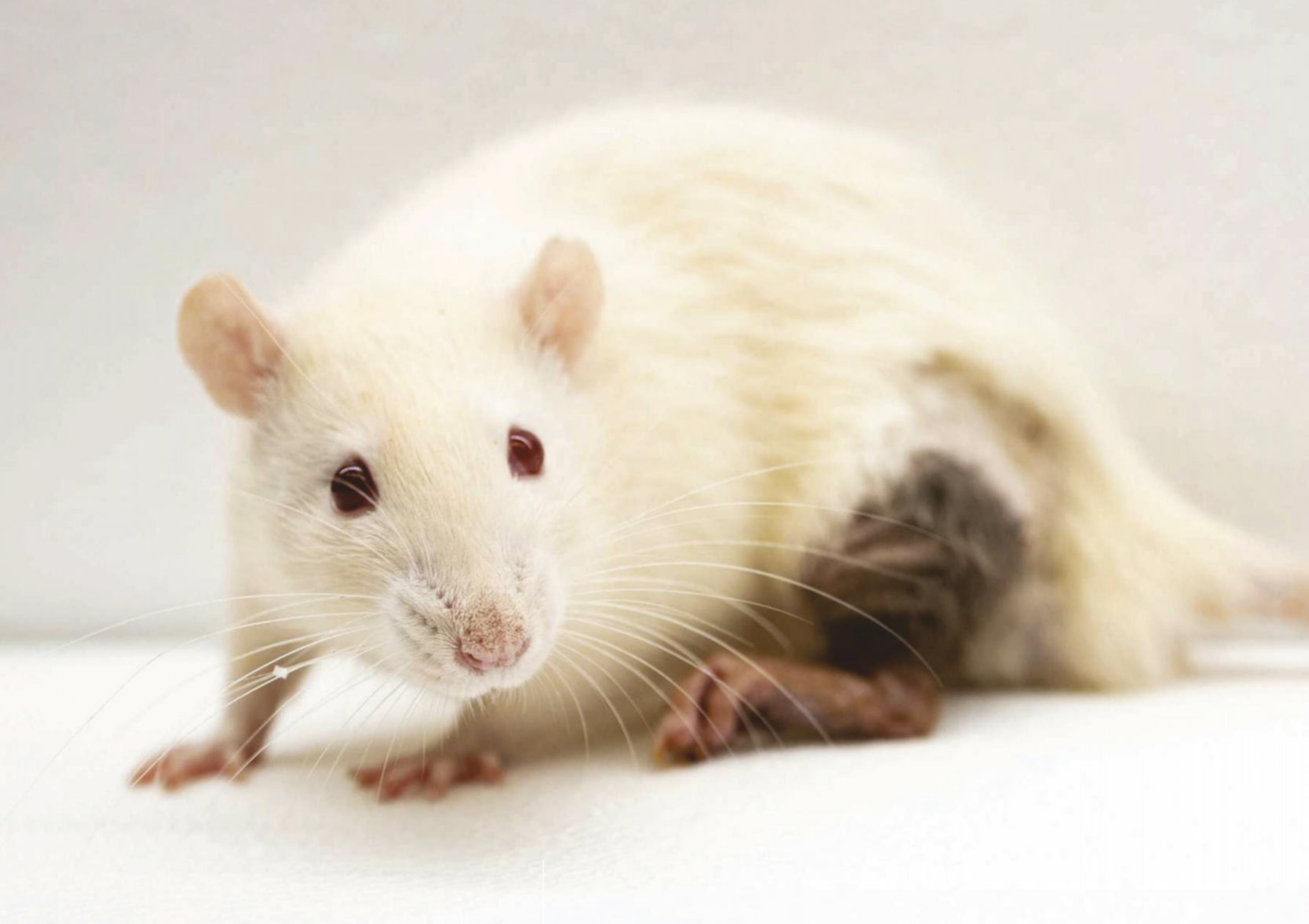
EXOPLANETS
A plethora of weird and wonderful worlds **p16**

GHOST SHIP
Storm Dennis brings an unusual visitor **p18**

HEATHROW HALTED
Plans to build a third new runway is unlawful **p22**

CORONA CRISIS
The seasonality and life cycle of COVID 19 **p24**

DISCOVERIES



LEG TRANSPLANTED ONTO RAT USING TRICK INSPIRED BY CANCER CELLS

Researchers at the University of Pittsburgh have successfully transplanted a leg from a black rat onto a white rat, by using particles that were engineered to trick the body into accepting foreign tissue as its own.

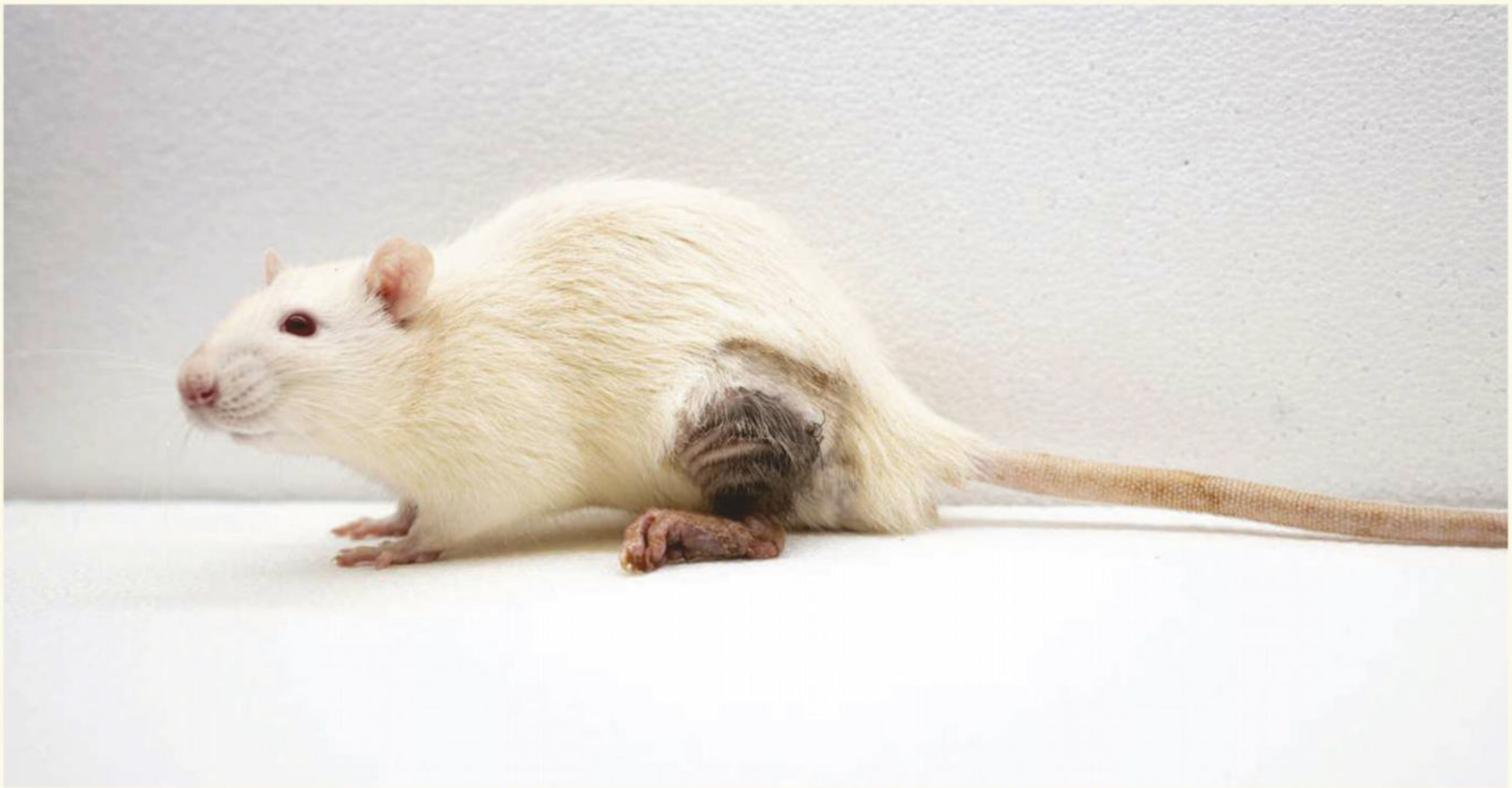
Inspired by a tactic that cancer cells use in order to evade the immune system, the cell-sized microparticles allowed the rats to develop permanent immune tolerance

Humble bumble Bees can identify by touch p16 **Tasty meal or deadly threat?** Ocean plastic smells the same as food p17
A mammoth question Mysterious circle of mammoth bones unearthed p19 **Cave fish** The largest troglobite ever discovered p26

News in brief

PLAYING VIDEO GAMES DURING MEALTIMES MAY MAKE US EAT LESS

Playing video games, or being distracted by technology during mealtimes may make us eat less, a study from the University of Illinois suggests. The team took a group of 119 young adults who hadn't eaten for 10 hours and gave them a meal of mini quiches to eat while they played a simple memory and attention video game for 15 minutes. They found playing the game while eating made the participants eat significantly less than they did when eating the same meal without distractions.



CCL22 tricked the body into thinking a new leg was native tissue

to transplants by releasing a protein secreted by tumours, known as CCL22. The CCL22 drew white blood cells to the site of the graft, and tricked the immune system into thinking the foreign tissue was native.

"It's like hacking into the immune system [and] borrowing a strategy used by one of humanity's worst enemies to trick the body into accepting a transplant," said senior author Steven Little of the Swanson School of Engineering at the University of Pittsburgh.

Though developing the technique was far from straightforward, the procedure itself is much simpler to administer than existing treatments. All it took was two shots of the treatment to create a seemingly permanent change. The microparticle-treated animals stayed healthy for as long as they were monitored – a little under a year, the researchers said.

"Instead of isolating cells from a patient, growing them up in the lab, injecting them back in and hoping they find the right location, we're packaging it all up in an engineered system that recruits these naturally occurring cells right to the transplanted graft," said lead author Dr James Fisher a postdoctoral researcher in the Pitt School of Medicine.

Currently, transplant patients need to take daily doses of immunosuppressant drugs to avoid organ rejection, leaving them vulnerable to cancer, diabetes, infectious diseases and a host of other ailments that come along with a weakened immune system. The risks of lifelong immunosuppression are particularly problematic when the transplant isn't a life-saving procedure. This can make it difficult for doctors and patients have to consider whether the benefits outweigh the risks, the researchers say.

"These drugs hammer the immune system into submission so it can't attack the transplanted organ, but then it can't protect the body either," said co-author Stephen Balmert, a postdoctoral researcher in the Pitt School of Medicine. "We're trying to teach the immune system to tolerate the limb, so that a transplant recipient can remain immunocompetent."

> "All it took was two shots of the treatment to create a seemingly permanent change"

UPMC X2, GETTY IMAGES

WHEN A BEE CAN'T SEE, THE BUMBLE MAKES DO WITH A FUMBLE

Blindfold a bee and it'll still be able to recognise a familiar object by touch alone. That's the finding of experiments carried out by scientists at Queen Mary University London. The scientists trained groups of bees to spot whether small spheres or cubes contained a tasty sugar solution. When the lights were then switched off and the bees could only feel the shapes, they were still able to identify the ones that held the sugar. The experiment also worked in reverse, so that bees trained to locate the sugar by touch could also spot the correct container in the light. These findings suggest that certain insects are capable of constructing mental images of objects, a skill only previously seen in humans, apes, monkeys, dolphins and certain species of fish.

EXOPLANETS

Inferno planet rains iron

If the world's astronomers ever came together and held a competition to name the most metal planet, chances are WASP-76b would be the clear winner. It's a planet with an atmosphere so extreme, that it rains molten iron.

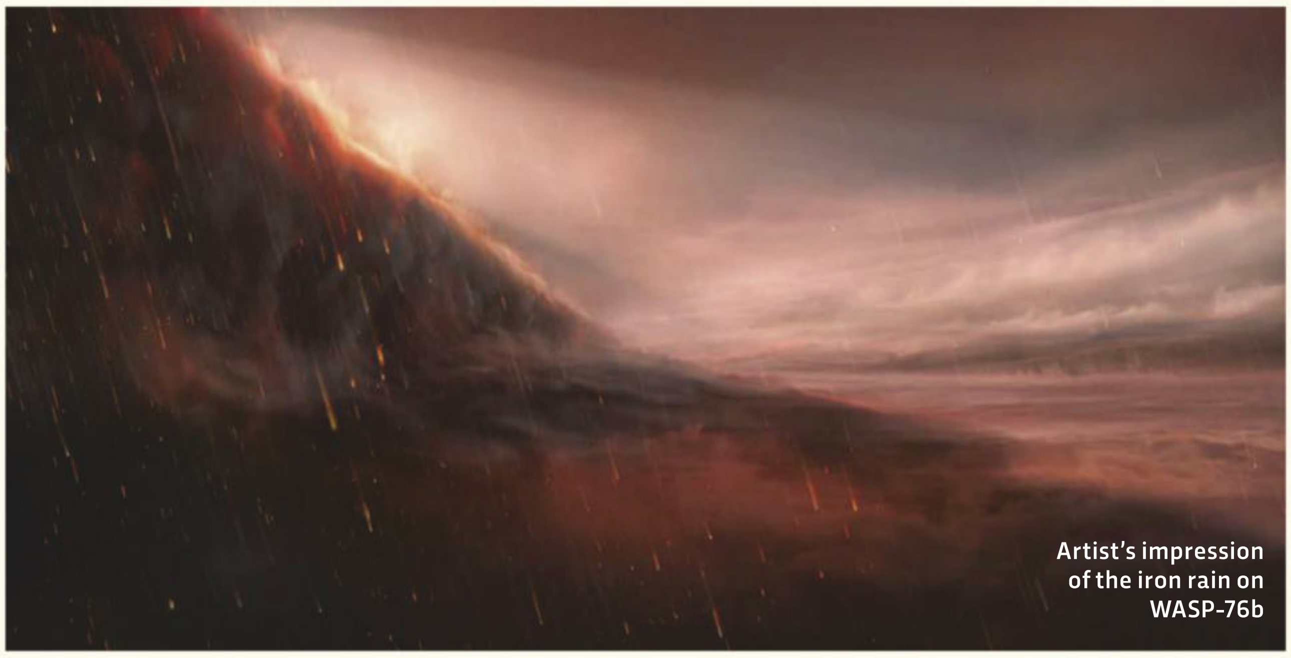
The gas giant exoplanet is located 390 light-years away from Earth, in the constellation Pisces. It was observed using a new instrument – dubbed ESPRESSO – built by a team at the University of Geneva and fitted to the Very Large Telescope (VLT), based at the European Southern Observatory (ESO).

WASP-76b is tidally locked, meaning it takes as long to rotate around its axis as it does to go around its parent star. This results in the planet only ever showing one side to the star, leaving its colder night side in perpetual darkness, much like our Moon. This gives it an ultra-hot day side with temperatures regularly reaching 2,400°C, which is high enough to vaporise metals. Strong winds rage across the planet's surface and carry the iron vapour over to the much cooler night side, where it condenses into iron droplets and falls as rain.

"We thought very early on, that we could use the instrument not only to discover new planets, but also to characterise those that are already known. However, until 2018, we didn't realise how powerful ESPRESSO really was," said Francesco Pepe, professor of astronomy at the University of Geneva.

ESPRESSO was built by the astronomy department at the University of Geneva, with help from teams in Portugal, Italy, Switzerland and Spain. Originally designed to hunt Earth-like planets around Sun-like stars, the instrument has proven to be much more versatile than first anticipated.

"Thanks to this technology, we have a completely new way of tracing the climate of the most extreme exoplanets," said the University of Geneva's Prof David Ehrenreich, who led the study. "One could say this planet gets rainy in the evening, except that it rains iron."



Artist's impression of the iron rain on WASP-76b

Going to extremes

WASP-76b isn't the only exoplanet that is completely different from the eight planets in our Solar System. Here are five more impressively bizarre extrasolar objects:

TrES-2B

If WASP-76b is the most metal planet, then TrES-2b must surely be the most goth. Identified in 2011 by the Transatlantic Exoplanet Survey, it's the darkest exoplanet ever discovered, reflecting less than 1 per cent of all light, less than coal.

55 CANCRI E

The top prize for most bling goes to 55 Canceri e. It's about twice the size of Earth, 40 light-years away in the constellation Cancer. Roughly one-third of the planet's mass is estimated to be made up of carbon. And with current temperature and pressure estimations, scientists think it's likely much of the carbon is in diamond form. Fancy.

GLIESE 436 B

And now for something truly weird: this exoplanet, just 30 light-years away in the constellation Leo, is thought to be covered in 'burning ice'. Even though its surface temperature is a blistering 440°C, powerful gravitational forces squeeze the surface so tightly that it remains solid.

PSR B1620-26B

Nicknamed Methuselah, at 12.7 billion years old, PSR B1620-26b is one of the oldest known exoplanets, 12,400 light-years away in the constellation Scorpius. For context, the Universe is around 13.7 billion years old, and the Solar System 4.6 billion years old.

TrES-4B

At more than 250,000km across, or 1.8 times the diameter of Jupiter, TrES-4b is one of the largest exoplanets discovered so far. It was spotted 1,400 light-years away in the constellation Hercules by the Transatlantic Exoplanet Survey in 2006.

Tasty meal or deadly threat? The plastic bag smells the same to this turtle

MARINE BIOLOGY

Ocean plastics turtle-y smell like food

The amount of plastic pollution in the oceans is rapidly increasing. This is problematic, as at least 700 species of marine animals – including sharks, whales, seabirds and turtles – can become entangled in it or mistake it for a tasty snack

While we know that some marine animals seem to eat plastic because it looks like jellyfish or some other food source, less research has been carried out into what plastic smells like to these creatures. But now a study from the University of North Carolina at Chapel Hill has found that the coating of algae and microbes that naturally builds up on ocean plastic causes it to give off the aroma of food.

The researchers took 15 captive-reared loggerhead turtles, each around five months old, and placed them in a laboratory aquarium. They then piped in aromas of clean water, clean plastic, turtle food, and plastic that had been soaking in the marine environment for five weeks. The turtles showed no reaction to the odours of clean water or clean plastic. But when they were exposed to the smells of ocean-soaked plastic or turtle food, they exhibited foraging behaviour – like poking their noses out of the water and showing increased activity.

"This finding is important because it's the first demonstration that the odour of ocean plastics causes animals to eat them," said Dr Kenneth J Lohmann, who took part in the study. "It's common to find loggerhead turtles with their digestive systems fully or partially blocked because they've eaten plastic materials. There also are increasing reports of sea turtles that have become ill and stranded on the beach due to their ingestion of plastic."

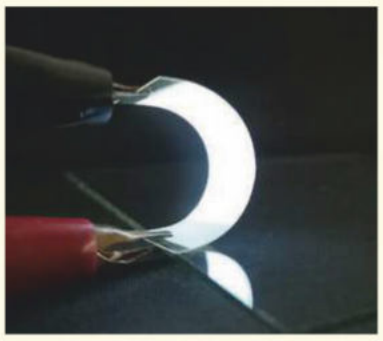
> "It's common to find loggerhead turtles with their digestive systems blocked because they've eaten plastic materials"

According to the researchers, areas of the ocean with dense concentrations of plastic may trick turtles and other animals into thinking that there is an abundant food source, when the reverse is true. "Once these plastics are in the ocean, we don't have a good way to remove them or prevent them from smelling like food," said Lohmann. "The best thing we can do is to keep plastic from getting into the ocean at all."

LARS CHITTKA, ALAMY, ESO

FISH SCALES COULD BE USED TO CREATE ECO-FRIENDLY WEARABLE ELECTRONICS

An eco-friendly wearable electronic display made from fish scales has been developed by a team based at Nanjing Tech University in China. The flexible film could make it possible to place glowing tattoo-like screens directly onto skin, they say. It was created by pouring a gelatin solution made from fish scales into a mould and letting it dry. It can then be layered with electrical and light-emitting components to create a display. The material is completely recyclable and biodegrades in soil in 24 days.



In numbers

4,173

The number of confirmed exoplanets (planets outside our Solar System) as of 1 February 2020

328

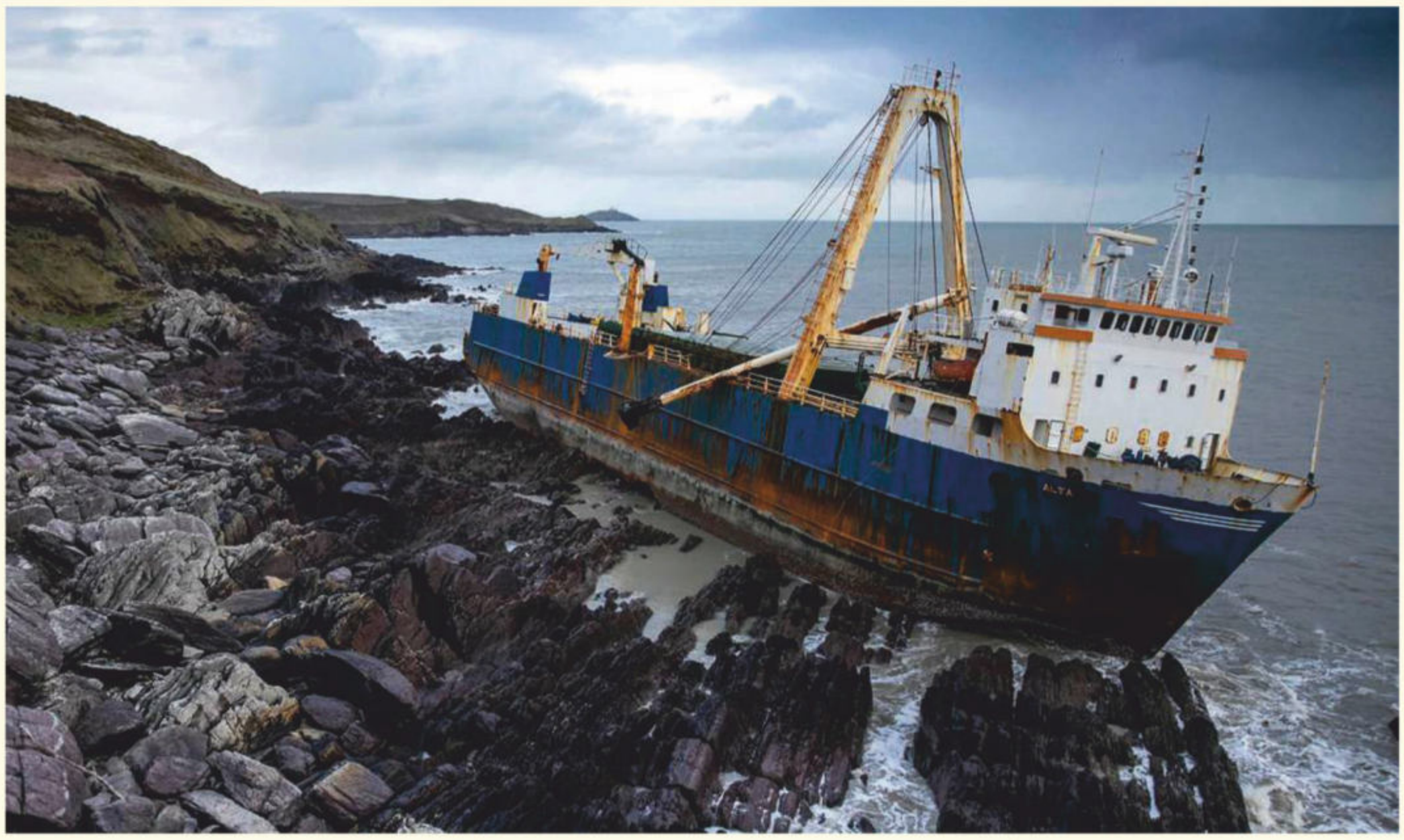
The number of days US astronaut Christina Koch spent on board the International Space Station – the longest continuous time spent in space by a woman.

2.7 METRES

The approximate diameter of a newly discovered mini-moon that temporarily orbited the Earth.

STORM DENNIS

Ghost ship washes up on southern Irish coast after unmanned journey across the Atlantic



In mid-February this year, Storm Dennis brought a highly unusual visitor to the coastline of County Cork: a 77-metre long ‘ghost ship’, called the *MV Alta*.

The cargo vessel had been drifting around on the Atlantic Ocean since it was abandoned near Bermuda in 2018, partway through a voyage from Greece to Haiti. The ship’s 10 crew members were rescued and taken to Puerto Rico by the coastguard, after a power outage left it stranded at sea. It is unclear exactly what happened to the vessel afterwards, but it was next spotted adrift in the mid-Atlantic in September 2019 by the British Royal Navy ship, *HMS Protector*.

Once abandoned, ships are simply left to drift freely on the many ocean currents, some of which can flow for many hundreds or thousands of kilometres.

The world’s waters are connected by a complex interconnected ocean circulation system, driven by wind, tides, the Earth’s rotation, the Sun’s rays, and variations in water density caused by differences in temperature and salinity. The shape of the ocean basin and any nearby landmasses can also affect the behaviour of the current.

The exact route that the *MV Alta* has taken is unknown, but it’s speculated that the ship headed toward Africa, then drifted north past the Iberian Peninsula and into the Celtic Sea, before berthing in County Cork.

To further deepen the mystery, it is as yet unclear who actually owns the ship. Discussions are now ongoing between the Irish Coastguard, Cork County Council, the Receiver of Wrecks and other relevant bodies over what to do with the vessel.

DOERS

Spending our spare cash on experiences rather than physical items makes us happier, a study at the University of Pennsylvania has found. More than 2,600 volunteers were split into two groups: those who were given products; and those who engaged in experiences such as dining out. People in the latter group reported higher levels of happiness throughout the experiment, regardless of item cost.

BUTTERFLIES

The record temperatures of the summer of 2019 have helped to boost the numbers of more than half of Britain's butterfly species, British charity Butterfly Conservation has reported.

Good month

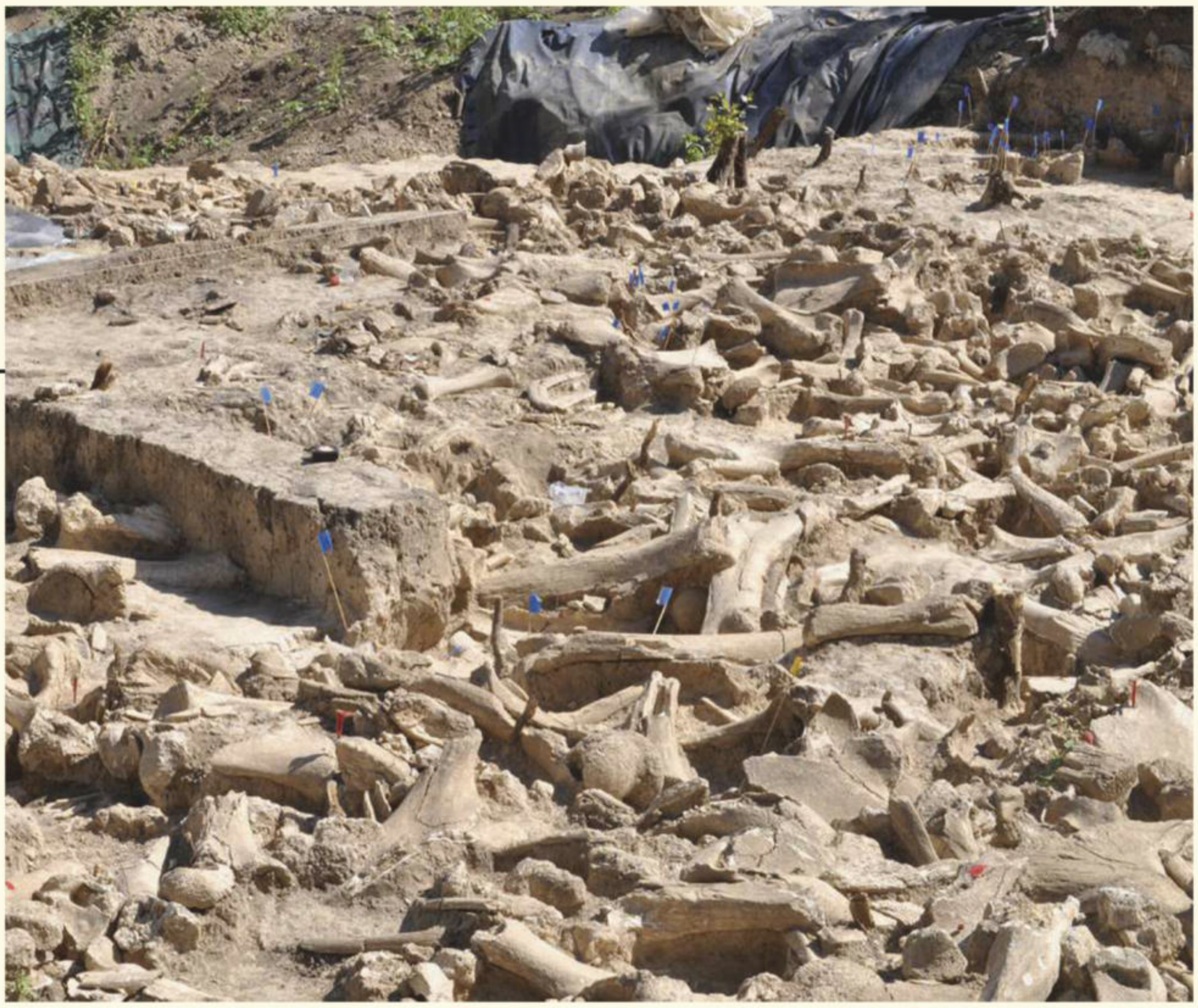
Bad month

PETROL CARS

Electric cars produce less carbon emissions than petrol cars in 95 per cent of the world's countries, even when taking into account the energy used for production and battery charging, a study by the University of Exeter has found. The only exception are countries that are still heavily reliant on coal power, such as Poland.

BURGER LOVERS

Next time you tuck into that bacon double cheeseburger it might be worth thinking about the impact meat production is having on fresh water supplies. The irrigation of feed crops for cattle accounts for one-third of all water use in the western US, and is depleting rivers and hurting fisheries, according to a study carried out in Virginia.



ARCHAEOLOGY

20,000-year-old circle made from mammoth bones unearthed in Ukraine

A mysterious bone circle made from the remains of dozens of mammoths has been dated as being 20,000 years old, by researchers at the University of Exeter. It's the oldest of its type ever found.

The 10m x 10m structure is situated just outside the modern village of Kostenki, roughly 500km south of Moscow, and is one of about 70 scattered across Ukraine and the western Russian Plain. It contains 51 mammoth jawbones and 64 mammoth skulls, along with small numbers of reindeer, horse, bear, wolf, red fox and arctic fox bones.

The researchers also found the remains of charred wood and other soft non-woody plants within the circular structure. This indicates that ice age humans may have been burning wood as well as bones for fuel, and that the communities who lived there had learned where to forage for edible plants.

The last ice age, which swept northern Europe between 75,000 and 18,000 years ago, reached its coldest and most severe stage around 23,000 to 18,000 years ago, just as the site at Kostenki was being built. Climate reconstructions indicate that summers were short and cool, and winters were long and cold, with temperatures around -20°C or colder. Eventually, the bone circles were abandoned as the climate continued to get colder and more inhospitable.

"These finds shed new light on the purpose of these mysterious sites. Archaeology is showing us more about how our ancestors survived in this desperately cold and hostile environment at the climax of the last ice age," said study leader Dr Alexander Pryor. "Most other places at similar latitudes in Europe had been abandoned by this time, but these groups had managed to adapt to find food, shelter and water."

GETTY IMAGES, ACS NANO, ALEX PRYOR ILLUSTRATIONS: JOE WALDRON

How did we get here? ▸▸▸

DEC 2019
Cases of pneumonia from an unknown cause appear in Wuhan, China.

EARLY 2020
Analysis suggests a novel coronavirus, originating from a live animal market.

23 JAN
The outbreak reaches more than 500 cases across China, Japan, Thailand and the US.

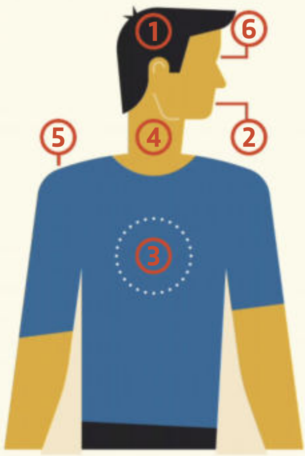
30 JAN
The World Heath Organization (WHO) declares a global health emergency.

Path to pandemic

EXPLORING THE RISE OF COVID-19

Infographic by James Round

Check for symptoms (symptoms by % of cases)



1. **Fever** (88%)
2. **Dry cough** (68%)
3. **Shortness of breath** (19%)
4. **Sore throat** (15%)
5. **Muscle or joint pain** (15%)
6. **Headache** (14%)

These symptoms don't confirm you have COVID-19 – they're similar to other more common illnesses, such as a cold or the flu.

Control the spread

Wash hands often with soap and water for at least 20 seconds

Use hand sanitiser if soap and water are not available

Cover coughs and sneezes with a tissue or your sleeve

Put used tissues in the bin straight away, then wash your hands

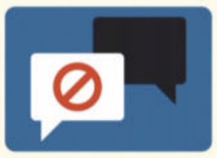
Avoid contact with people who are unwell

Do not touch your eyes, nose or mouth

Self-isolate if symptoms appear

Stay at home. Avoid work, school and other public places

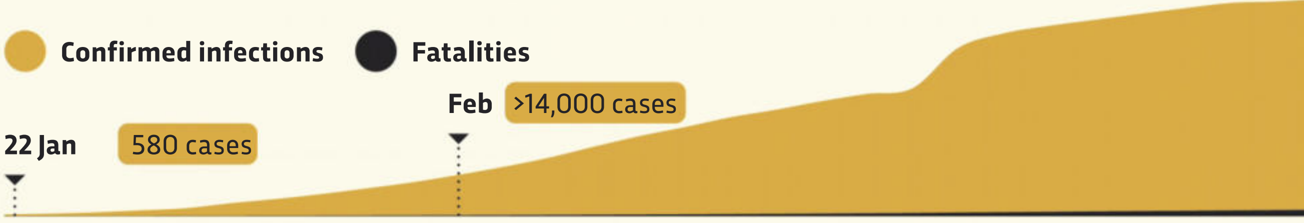
Use friends, family members or delivery services for errands



Avoid visitors to your home

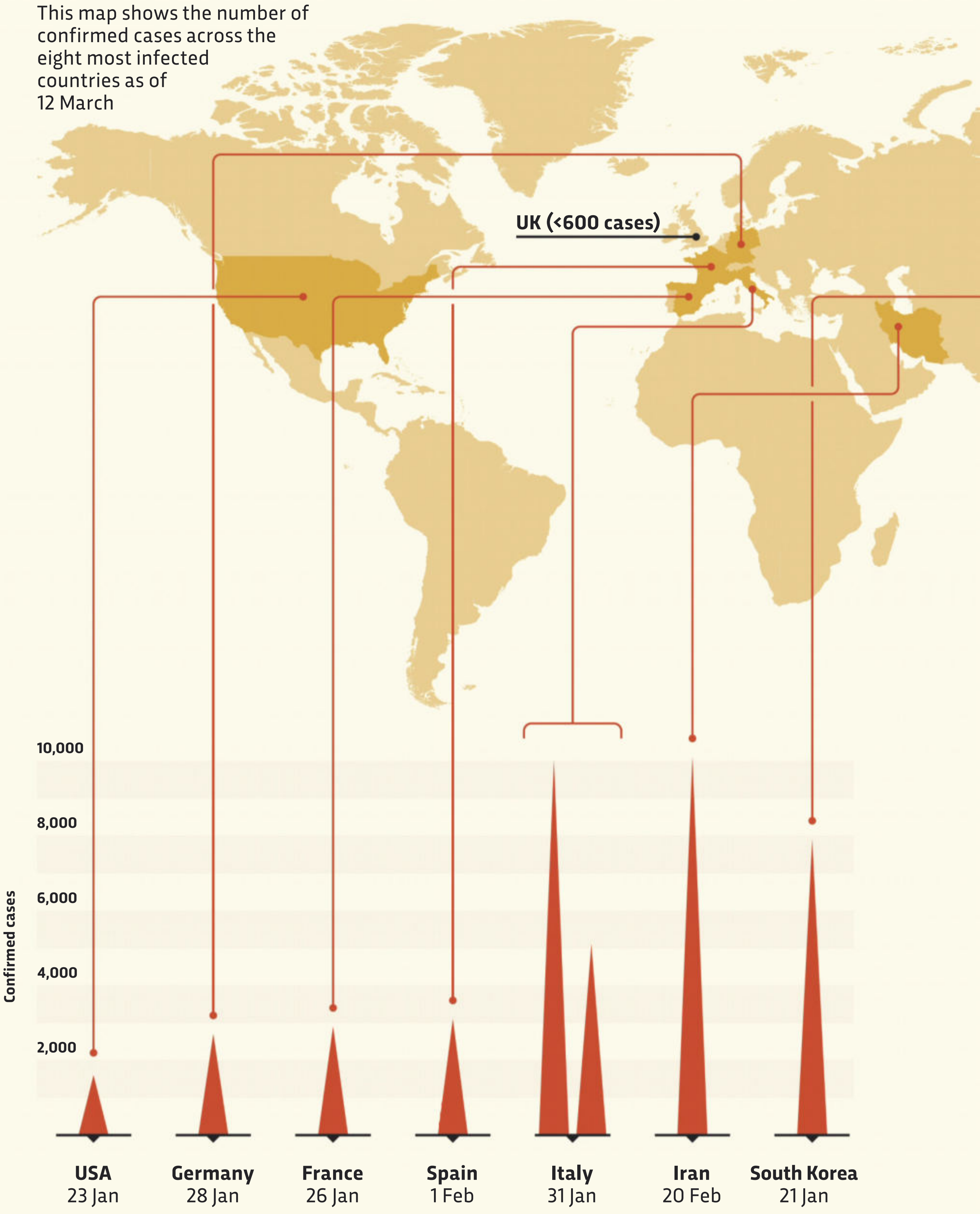
You may need to do this for up to 14 days

Infection rates and fatalities over time



By 12 March, there were almost 135,000 confirmed cases worldwide...

This map shows the number of confirmed cases across the eight most infected countries as of 12 March



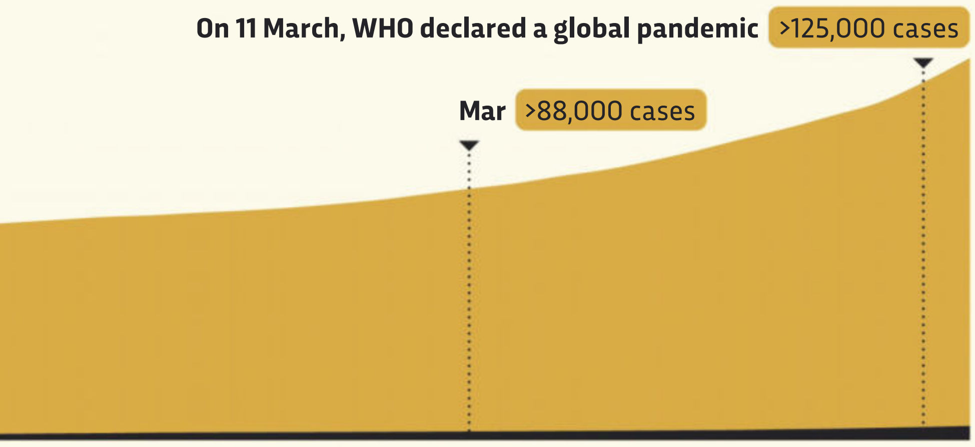
Sources: Infection and fatality data from **worldometers.info**. Outbreak comparison data from *National Geographic*.

11 FEB
The new virus is given a name: SARS-CoV-2. Cases fast approach 50,000 globally.

14 FEB
France announces the first death in Europe, the fourth outside mainland China.

28 FEB
Cases across Europe spike with Italy at the epicentre. Global cases near 100,000.

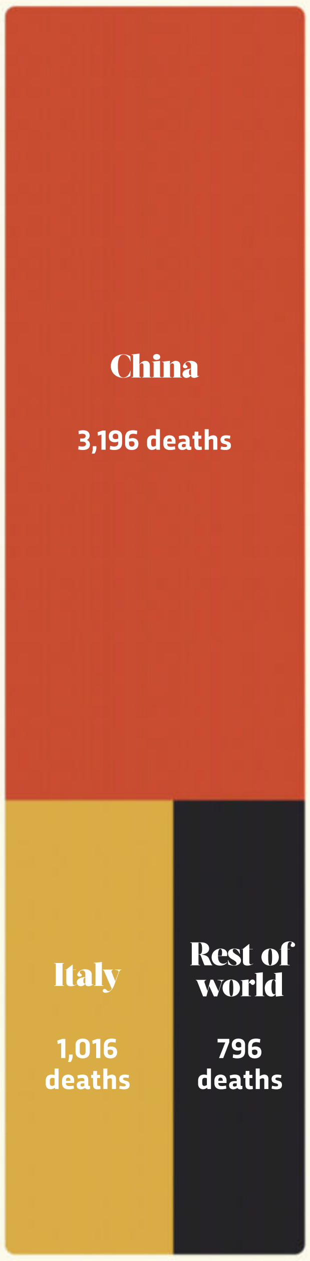
11 MAR
With over 125,000 cases, the WHO declares COVID-19 to be a pandemic.



... and of those cases, almost 5,000 people had died.

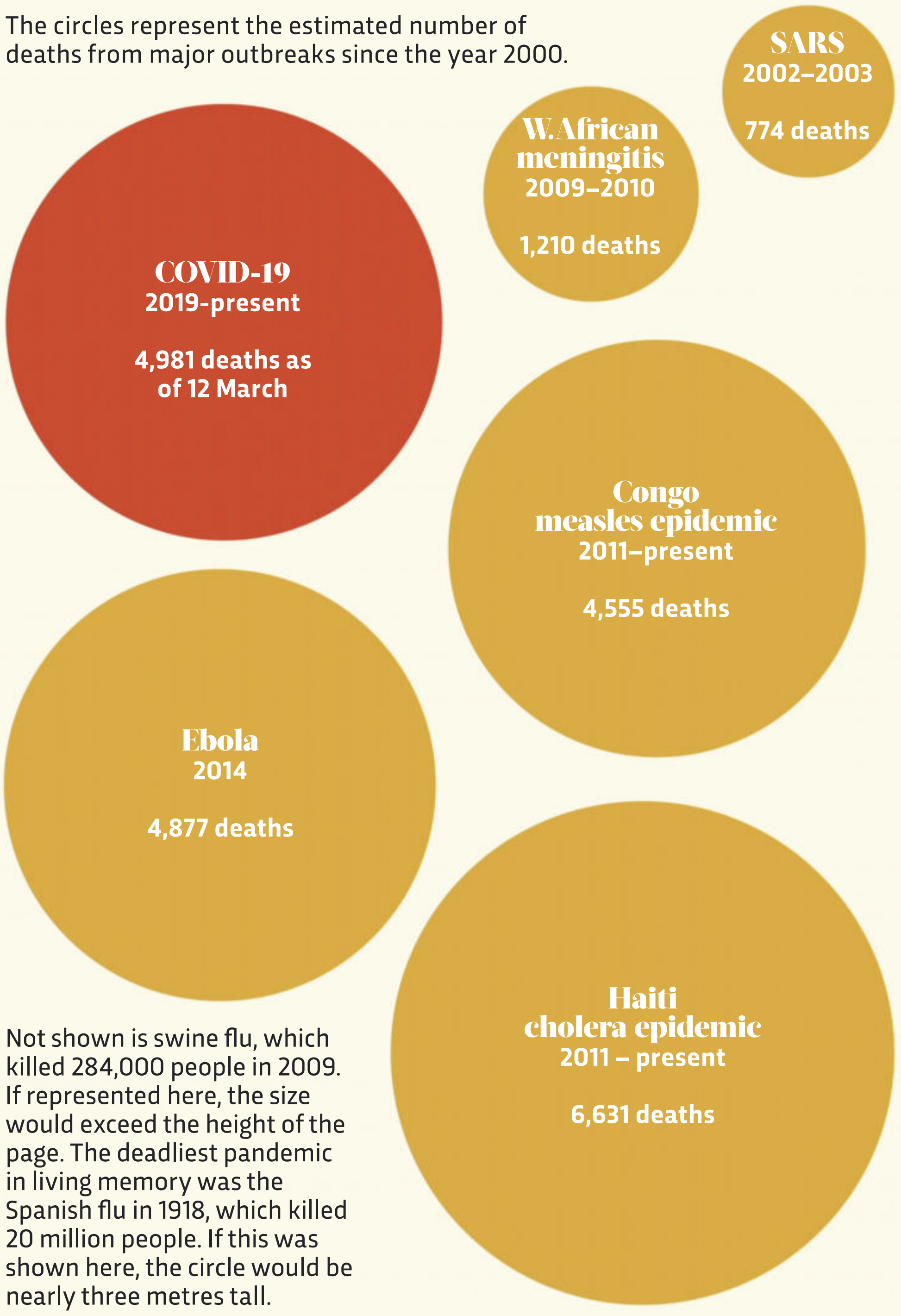
Most at risk are the elderly and those with underlying health conditions. For over 80s, there's an almost 15 per cent fatality rate.

Wuhan
China
Dec 2019
Each country's first case



How does COVID-19 compare to other outbreaks?

The circles represent the estimated number of deaths from major outbreaks since the year 2000.



Not shown is swine flu, which killed 284,000 people in 2009. If represented here, the size would exceed the height of the page. The deadliest pandemic in living memory was the Spanish flu in 1918, which killed 20 million people. If this was shown here, the circle would be nearly three metres tall.

Heavily infected countries have taken serious measures

Self-isolation recommended

Travel restricted

Sporting and other events cancelled

Schools, universities and offices closed

The global economy is at risk as the markets drop...

£160bn **-10%**

Value lost off the FTSE 100 on 12 Mar

...but sales of some products have risen, causing shortages

255% Hand sanitiser

944% Toilet paper

Other sources include BBC, Business Insider, Daily Mail, World Health Organization, Our World in Data, The New York Times, The London Stock Exchange, Kantar and Wikipedia. Data correct as of March 2020.

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

Friends of the Earth
friendsoftheearth.uk
NO CLIMATE WRECKING THIRD
NO THIRD RUNWAY
Stop Heathrow Expansion
stopheathrowexpansion.co.uk

A campaigner celebrates after hearing the ruling that another runway at Heathrow would be unlawful

WIND WIN

The UK government has lifted its opposition to subsidies for onshore wind power after a four-year ban. The next round of clean energy auctions, set to be held in 2021, will allow both onshore wind and solar to compete for subsidies once more, it said. Local communities will have a "definitive say" on whether projects are allowed to proceed, the government said.

Despite the fact that there is strong support from the public for wind power, the number of new onshore wind farms dropped dramatically when the ban was implemented in 2016. Solar and onshore wind power are now the cheapest sources of new electricity in the UK.

CLIMATE

Heathrow expansion plans stopped in their tracks

Plans to build another runway at Heathrow airport have been declared unlawful for failing to take the UK's climate commitments into account

On Thursday 27 February, the UK Court of Appeal ruled that the government's decision to approve a new third runway at Heathrow is illegal, as it breaches its own policy commitments under the 2015 Paris Agreement on climate change.

Aviation is a rapidly expanding sector globally, and one of the most carbon-intensive forms of transport. However, its distribution is uneven. According to a Department for Transport survey, in England, roughly 20 per cent of people take 70 per cent of all flights, while around half of people do not take any flights at all in a given year. A third runway at Heathrow would bring an extra 700 planes per day through the airport, already one of the busiest in Europe.

"The Paris Agreement ought to have been taken into account by

LOW CARBON SHIPS

Nearly half of container ship voyages between China and the US could be made using hydrogen-powered ships – without the need for extra fuel stops.

Hydrogen made using renewable electricity is a zero-carbon fuel, but less energy dense than fossil fuels. This means ships need to carry more of it per kilometre travelled – a potential problem for long distance trips. But a new report from the International Council on Clean Transportation (ICCT) found that in reality 43 per cent of the China-US trips could be made with hydrogen without adding extra fuel capacity or stopping at more ports.

the secretary of state in the preparation of the [Heathrow policy] but was not," the ruling by three Court of Appeal judges said.

The challenge had previously been dismissed in the High Court in May 2019.

Grant Shapps, the UK's transport minister, stated on Twitter that the government would not be appealing the decision. The government could now decide to draw up a new policy document trying to better address climate change, or drop expansion plans altogether. However, Heathrow has said it will appeal to the Supreme Court.

Legal action group Plan B, which brought the case against the government, welcomed the government's decision to accept the ruling. "Some sanity is finally prevailing," said Tim Crosland, director of Plan B, in a statement. "It's now clear that our governments can't keep claiming commitment to the Paris Agreement, while simultaneously taking actions that blatantly contradict it."

The Court of Appeal's decision is thought to be the first major legal ruling in the world to be based on the Paris Agreement. Tim Johnson, director of non-profit campaign group the Aviation and Environment Federation (AEF), said the ruling is hugely significant. "It confirms the relevance of Paris to the aviation sector and holds a government legally accountable for its international climate commitments for the first time," he said.

Following the ruling, it emerged the government could face another climate change-based challenge in court over its £29bn road expansion programme from sustainable transport group Transport Action Network.

"We think the [programme] is challengeable on the same grounds as Heathrow," wrote Chris Todd, Transport Action Network's director, on the group's website.

> **"It's clear our governments can't keep claiming commitment to the Paris Agreement, while taking actions that contradict it"**

INSPIRED EXPIRED

GREEN PEACE

Better design and maintenance of green spaces has the potential to reduce violent crime and keep communities safer.

SALT OF THE EARTH

Engineers at Yale have developed a 'synthetic mangrove' that mimics the ability of real mangroves to desalinate seawater and could be used to clean up salty floodwater that can damage plant life.

PALM BIOFUELS

Biodiesel made from palm oil grown on newly deforested land results in more greenhouse gas emissions than burning fossil fuels, a study carried out by the American Chemical Society has found.

HOME DELIVERY

Ordering deliveries via an online-only shop has a higher carbon footprint than going to a physical shop 81 per cent of the time, a study shows. However, emissions are lowest for home delivery from a physical shop.

IT'S EASY BEING GREEN

PLANT FOR BUTTERFLIES

From red admirals to hummingbird hawkmoths, people love to spot butterflies and moths in their gardens. Sadly, many of the UK's species are in decline. To help tackle this, the Wildlife Trusts and the Royal Horticultural Society (RHS) are asking people to provide support in their gardens. Making nectar-rich flowers available throughout the year and delaying cutting back borders until late winter is a good start. Keeping an open area for wildflowers and grasses will attract egg-laying females, while hops, holly and nettles are a good food source for caterpillars. Visit **bit.ly/garden-butterfly**

GETTY IMAGES X6

Dr Mike Skinner virologist

Horizons

How might seasonal changes affect the coronavirus pandemic?

Everything from temperature differences to changes in social behaviour can affect the way a virus spreads, but what does the future hold for COVID-19?

WHAT DOES SEASONALITY OF A VIRUS MEAN?

We are all familiar with viruses that routinely circulate, such as influenza, the common cold and chickenpox, which is caused by the varicella-zoster virus, VZV. These viruses are 'endemic', which means they are regularly found among particular people, or in a certain area. Some of them, such as VZV, circulate all year round, while others, such as influenza, cause more infections in the winter. We say that these virus infections show 'seasonality'.

In some seasons, the peaks become so high that they are called 'epidemics', meaning a widespread occurrence of an infectious disease in a community at a particular time. COVID-19 is not yet endemic – having only emerged last year. However, it is an epidemic, in that it is still spreading rapidly. It can therefore only display seasonality if, or when, it becomes endemic.

WHY DO VIRUSES SHOW SEASONALITY?

It's still not fully established, but we believe a number of parameters come into play. Not all viruses show higher peaks of infection in the winter. For respiratory viruses, which do peak in winter, an important factor is the ability of the actual virus to resist environmental stresses. These include heat, humidity and UV light.

Another important factor that affects seasonal virus transmission is our behaviour. In winter, we tend to be more closely crowded together, and create higher relative humidities in our homes because we remain inside and turn up the heating.

HOW DOES THAT APPLY TO COVID-19?

There was some hope that if we could delay the peak of this epidemic into the late spring and summer, that we'd reduce transmission. But it's hard to know how far that would go with a novel virus like this. It's worth pointing out that when it's summer in the northern hemisphere, it's winter in the southern hemisphere. So at the same time as influenza infections are low during our summer, they're high in Australasia and South America. In tropical and subtropical regions you don't really get the seasons we're used to, and influenza infection rates stay pretty level. This suggests that relative humidity is probably the most important factor. The World Health Organization has emphasised that COVID-19 is transmitting everywhere, so the suspicions are that seasonality may not have a huge impact on reducing the spread.

WHAT OTHER FACTORS ARE INVOLVED IN HOW A VIRUS SPREADS?

What we anticipate for this virus is based mainly on our experience with flu, particularly back in 1918 and even in 2009. But this is a different virus and may behave in subtly different ways.

ALAMY

> "WHO has emphasised that COVID-19 is transmitting everywhere, so seasonality may not have a huge impact"

POLICIA
POLICIA LOCAL

Police cordon tape during the COVID-19 lockdown at Levante beach in Benidorm

Previously, we've seen multiple waves, and could – if we didn't take action – also expect to see multiple waves of COVID-19. We're in the first wave now. If infection rates were to fall over the summer, due to seasonal factors or to our control efforts, we could expect to see one next winter, while there's still a substantial proportion of people who aren't immune. The government is taking that possibility into account and is planning for control measures.

WHAT CAN WE LEARN FROM PREVIOUS CORONAVIRUSES?

My first employment was working on a coronavirus back in the 1980s, and we knew of two then, OC43 and 229E. It's probable that tens of thousands of years ago, they first emerged from bats, or other animals, into humans as novel, and possibly dangerous, viruses that gradually spread across the world with population movements, mutating and becoming tailored to co-existence with us. They tell us quite a lot that will be important as we move forward with controlling or eradicating COVID-19. Those two viruses haven't changed much, and yet people get colds every winter caused by them. We think about 15 to 20 per cent of colds are caused by coronaviruses. There's not been sufficient work done on them to fully understand them, as funders don't spend a lot of money on viruses that don't cause much by way of disease. We know that influenza keeps circulating because it keeps mutating and avoids our existing immunity – we say they undergo 'genetic drift'. But if a virus is to keep circulating, like the older coronaviruses, and isn't changing much, there's only really one other explanation for that as far as I can see: the immunity they induce is probably fairly short-lived. Some virus infections provide almost life-long immunity, but for others, it's not so long. For example, we can catch norovirus one year, then a year or two later we can get it again. Should that be the case for COVID-19, it would have important implications for its epidemiology and control.

WHAT IS LIKELY TO HAPPEN NEXT?

At the moment we're all non-immune, but as people catch and recover from COVID-19, we expect the vast majority to become immune. It is likely that more people will become immune during subsequent waves and we can expect the virus to return until, at current estimates, 60 per cent of the population have acquired immunity. At this point, we'll have established 'herd immunity', where there aren't enough non-immune people around for the virus to cause any more epidemic peaks. In fact, at this point, the virus is liable to become endemic, and we might see small seasonal peaks of infection among members of the population who are non-immune, or who have been born since the earlier waves. If that does happen, we'll be dependent on the development, testing, introduction and roll-out of an effective vaccine to stop the virus circulating. That, of course, will need to be achieved globally, if we are to eradicate this virus and prevent it from posing an ongoing threat.

by **DR MIKE SKINNER**

*Mike is a virologist based at Imperial College London. **Interviewed by** BBC Science Focus **commissioning editor Jason Goodyer.***

Meghalaya, northeast India

CAVES

World's largest cave-dwelling fish discovered in India

The white, eyeless fish was found deep inside a network of limestone caves by subterranean explorers in Meghalaya, northeast India, in January this year. At 40cm long, it's the largest cave-dwelling fish ever discovered...

1. The researchers' interest in exploring the area was first piqued by locals, who reported seeing an unusual fish in this cave – Krem Chympe. Totalling 10.5km in length, it's the fifth-longest cave in India, and is home to a 3.5km-long subterranean river and a series of giant underground lakes. This picture shows Simone Buchmann wading through the water towards Rich Hudson, as they prepare for another trip underground.

2. Krem Chympe features more than 50 naturally formed dams, one of which can be seen in the foreground of this image. Torches held by Nicky Bayley and Marie-José Gilbert create an eerie glow.

3. Krem Ladaw, the cave in which the team found the fish, has three intimidating vertical pitches. During the monsoon season, rainfall makes passage through the caves impossible.

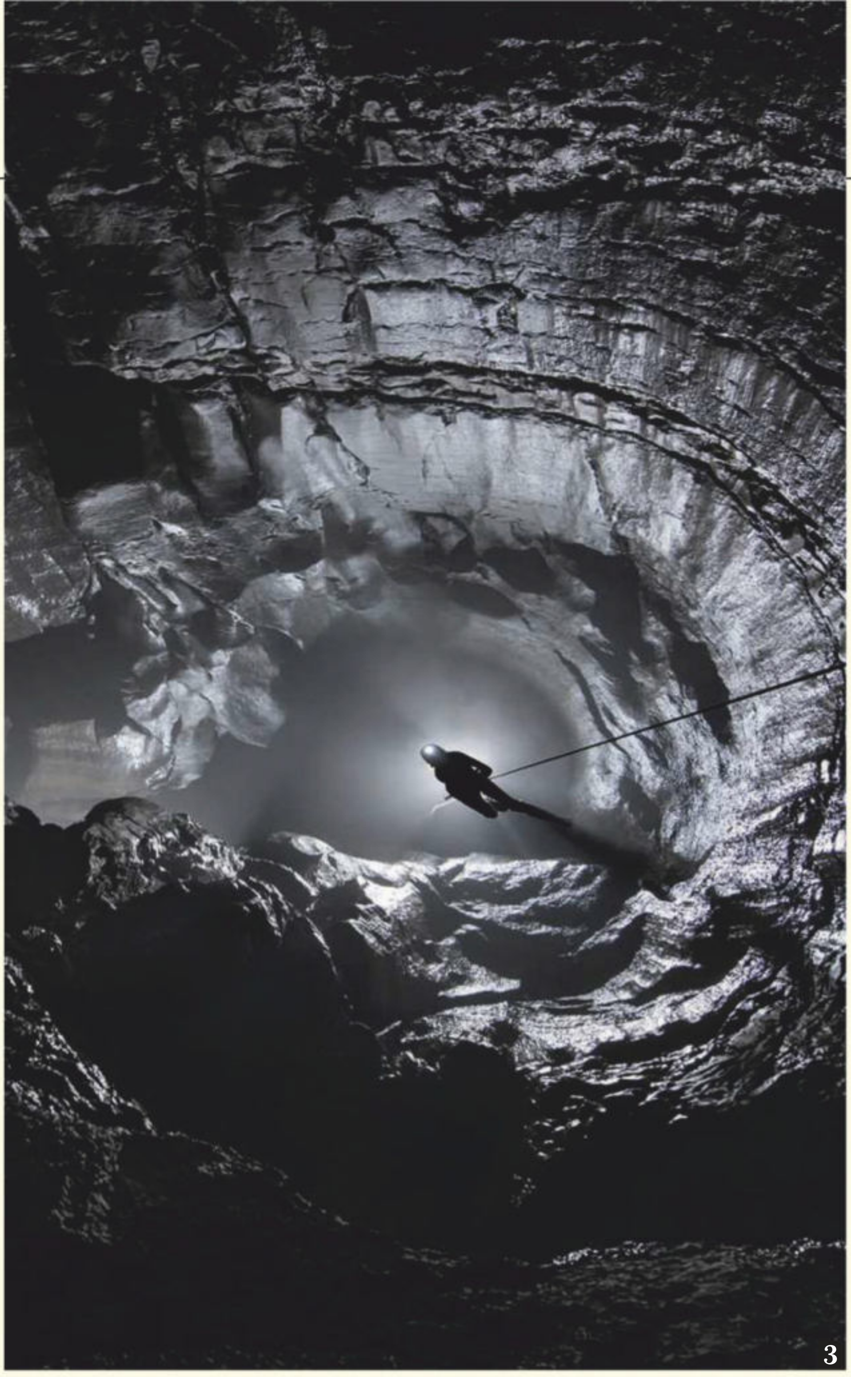
4. This image shows Bayley catching one of the blind cave fish as Dr Dan Harries, a marine biologist based at Heriot-Watt University, Edinburgh, watches on. Although the fish is eyeless, it does appear to have some ability to sense light.

5. During the expedition, the team collected three eyeless fish from Krem Ladaw. The fish is thought to be related to the surface-dwelling golden mahseer, a type of carp, albeit lacking the latter's eyes and pigmentation. The fish could be partway through evolving into an entirely new species.

2

1

ROBBIE SHONE / SHONEPHOTOGRAPHY.COM



3

4

5

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Hand-washing | **Herd immunity**

BBC iPlayer

Watch *Coronavirus: What You Need To Know* for the latest information and advice on coronavirus
bit.ly/BBC-corona-info

REVIEW

CORONAVIRUS: IS HAND-WASHING REALLY THE BEST THING WE CAN DO TO STOP THE SPREAD OF COVID-19?

The government's advice on coronavirus asks the public to wash their hands more often. But how could hand-washing protect us from the virus?

“When it comes to stopping the spread of the serious infection in this country, the public have a huge role to play”

BBC *Visit the BBC’s Reality Check website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHY ARE WE BEING ADVISED TO WASH OUR HANDS?

Coronavirus is a respiratory illness, meaning it is mostly spread through virus-laden droplets from coughs and sneezes. If you don’t catch coughs and sneezes in a tissue and dispose of it, the virus can end up on surfaces. If someone touches that contaminated surface, the virus can transfer onto their hand. If you have the virus on your hands, you can infect yourself by touching your eyes, mouth or nose. You might think that you don’t touch your face very often, but a 2015 study found that people touch their faces an average of 23 times an hour.

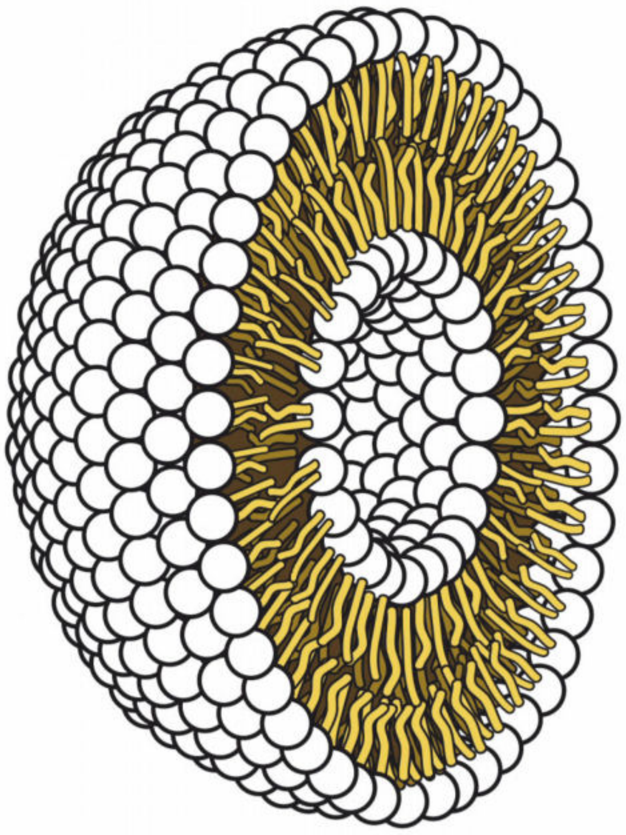
While washing your hands is useful in preventing yourself from getting infected, this is not the main reason the government recommends it. “It’s all about stopping the spread,” says Sally Bloomfield, honorary professor at the London School of Hygiene and Tropical Medicine. “When it comes to stopping the spread of the serious infection in this country, the public have a huge role to play.”

DOES SOAP KILL CORONAVIRUS?

Coronavirus is an ‘enveloped virus’. This means it has a protective outer layer known as a ‘lipid bilayer’. Each molecule making up this layer is shaped like a tadpole, with a water-loving (hydrophilic) head and a water-hating (hydrophobic) tail. These molecules arrange themselves into a ‘bilayer’: two layers piled on top of each other into a sheet, with tails pointing inwards and heads pointing outwards. The molecules are pulled closely into each other to protect the hydrophobic tails from the water in your respiratory droplets when you cough or sneeze. The hydrophilic heads are ‘sticky’, meaning the virus is effective at adhering to your hands – perfect for a microbe that’s trying hard to infect you.

Soap molecules also have this tadpole structure, which is what makes it so useful. Because the soap molecules are so similar to the ones making up the outer layer of the virus, the molecules in the lipid bilayer are as strongly attracted to soap molecules as they are to each other. This disrupts the neatly-ordered shell around the virus, dissolving it in the running water and killing the virus.

GETTY IMAGES ILLUSTRATION: MARIANA RUIZ VILLARREAL



ABOVE Coronavirus has a protective outer lipid bilayer. It’s made up of tadpole-shaped molecules with water-loving heads, and water-hating tails

DOES ANTIBACTERIAL HAND SANITISER KILL VIRUSES?

Yes. Alcohol-based hand sanitiser will kill viruses if soap and water are not available. Alcohol is an antiseptic and can kill enveloped viruses such as coronavirus, but make sure it contains 60 to 95 per cent alcohol. However, if your hands are visibly dirty, you need to use soap and running water to clean the dirt off.

WILL HAND-WASHING STOP ME FROM CATCHING THE VIRUS?

It’s impossible to know whether any particular case of coronavirus could have been prevented by better hand-washing. While it is possible to contract coronavirus from touching your face with virus-contaminated hands, you can also catch it directly from the coughs or sneezes of an infected person. So, while washing your hands won’t eliminate your risk of infection, it’s a sensible and powerful safety measure. “It’s a little bit, I think, like wearing a car seatbelt, in that it’s unlikely you’ll get infected at the present time, in the same way as you’re unlikely to have a crash when you go out in your car,” says Bloomfield. “You still go out in your car, but you always belt up your seatbelt.”

We do, however, know that hygiene measures – hand-washing, self-isolating when ill, disposing of tissues, etc. – do prevent the spread of respiratory diseases. Following the 2003 outbreak of SARS-CoV in Hong Kong, the Department of Health in China wanted to know how effective the government’s efforts at containing the disease were. Since ➜

SARS-CoV (also a type of coronavirus) was a new strain, there was no benchmark for how far it was likely to spread. What they *could* measure was the incidence of seasonal respiratory illnesses such as the flu. Compared to the average numbers over the previous five years, the incidence of these seasonal illnesses dropped. The difference was particularly clear in the months of April to June, when the public were the most stringent with their hygiene practices.

HOW SHOULD I WASH MY HANDS?

1. Start by wetting your hands with water. It doesn't matter whether it's hot or cold: a 2017 study from Rutgers University in the US found that cold water was just as effective as hot at removing *E. coli*.
2. Next, apply either bar soap or liquid handwash. Although some studies have shown that bacteria can live on the surface of a bar of soap, others have found that sharing a bar does not transmit disease.
3. Thoroughly rub the soap all over your hands, making sure not to miss your thumbs, or between your fingers and your fingertips. This part of the process should take 20 seconds. The NHS recommends singing *Happy Birthday* through twice to count out 20 seconds, but you could choose any song with a 20-second chorus, such as Dolly Parton's *Jolene*, or *Staying Alive* by the Bee Gees.
4. Rinse your hands well to remove the soap. Dry them thoroughly, preferably with paper towels.

What you do after you've washed your hands is important, too, says Bloomfield. "If you are, say, on an aeroplane or a train, you can wash your hands in the toilet, but you've then got to walk back to your seat," she says. "On an aeroplane, you're going to be grabbing all the seatbacks that have been grabbed by other people. So, wash your hands, then use a hand sanitiser when you get back to your 'safe place', so for example, when you get back to your train seat or plane seat and you're then not going to move around."

CAN I WASH MY HANDS TOO MUCH?

All of this extra washing could dry out the skin, so make sure you moisturise your hands too. "If the skin is breaking down or raw, then the soap and alcohol disinfectants do not work as well," Dr Craig Shapiro, a specialist in paediatric infectious diseases in Delaware, US, told the *Washington Post*. "Also, when the skin is chapped and broken, it's uncomfortable, and people can be less likely to wash their hands to prevent transmission of germs and infection."

by **SARA RIGBY**

Sara is the online assistant at BBC Science Focus.

ANALYSIS

HERD IMMUNITY: CAN IT SAVE US FROM CORONAVIRUS?

How does herd immunity work, and is it a useful way to keep infection rates down?

In mid-March, as coronavirus spread across the UK, Sir Patrick Vallance – the UK government's chief scientific advisor – said that, to control the impact of the virus, the country would need to build up "some degree of herd immunity" and that about 60 per cent of the population would need to become infected for this to happen. His comments soon came under fire. Over 500 scientists from UK universities wrote to the government, saying that going for herd immunity would risk more lives than necessary.

COVID-19 has an estimated fatality rate of around 1 per cent. If 60 per cent of the UK population became infected – some 40 million people – that could equate to hundreds of thousands of deaths. The Department of Health and Social Care has since clarified that herd immunity is not part of the

GETTY IMAGES

WHAT IS HERD IMMUNITY?

Herd immunity is what happens when enough people are immune to a disease (in this case, COVID-19) for the chains of transmission to be broken. As more people become immune, infected people are less able to pass on the disease, and the spread of the disease slows down. This provides an indirect form of protection for those who are not immune. Usually, individuals become immune through vaccination. But there isn't yet a vaccine for coronavirus, so herd immunity could only currently be achieved if enough people contract the disease and recover, developing an immunity to it in the process.

UK's action plan to tackle coronavirus, but is "a natural by-product of an epidemic".

So where did the 60 per cent figure come from? And will we eventually experience the positive effects of herd immunity?

The ease with which a disease spreads is measured using the 'reproduction number', R0, which is the average number of people expected to catch the disease from a single infected person. For COVID-19, R0 is estimated to be around 2.5. Flu has an R0 of 1.3, while measles has an R0 as high as 18. The proportion of the population needed to become immune to achieve herd immunity (the 'herd immunity threshold') is calculated by 1 - (1/R0). For coronavirus, this gives the threshold of 60 per cent that was quoted by Vallance.

Crucially, a disease's infectiousness isn't set in stone. Measures can be taken to make it harder for a disease to spread, reducing the threshold. A few days after Vallance's comments, Boris Johnson introduced new guidelines that help to do this, including stopping non-essential contact and travel.

"All the measures that we have put in place will reduce R0," says Prof John Edmunds at the London School of Hygiene and Tropical Medicine. Edmunds is a member of the Scientific Pandemic Influenza Group on Modelling, which is providing advice to the government. "Exactly by how much is hard to say at this time, as we have never tried these measures before. But overall, we would expect them to reduce R0 to a low level – even to below 1."

If this number is kept low for long enough, then fewer people will need to become immune to reach the herd immunity threshold, and the epidemic will slow. But how long it would take to reach this point is tough to predict. Edmunds notes that, even once herd immunity is reached, the epidemic won't suddenly stop, as there will still be infectious people generating new cases. "One other important strategy is to lower the number of infectious individuals so it is low at the point when the epidemic peaks," he says.

There are currently three big unknowns when it comes to the coronavirus, says Dr Jeremy Rossman, a virologist at the University of Kent. Each of these will affect the disease's future infectiousness. First, we don't know whether the coronavirus will track our seasons. If the coronavirus prefers colder weather, like flu, then the epidemic could gain a second wind during the winter. Second, we don't know how much this coronavirus will mutate. "Changes to the virus could make it better at evading our immune systems, or more easily transmitted," says Rossman. And third, we don't know how long those who are infected are subsequently immune for. Some other viruses in the coronavirus family, such as those that cause the common cold, only provide immunity for around three months. There's evidence for short-term immunity with COVID-19, says Rossman, "but we don't have the data yet to know whether it provides long-term immunity." Rossman estimates that we'd need to be immune for at least a year, possibly two, in order to build up herd immunity. If this isn't the case, he says, our best hope for herd immunity might be a vaccine, although this is still believed to be at least a year away. For now, he says that the best actions that governments can take are to keep the public informed, keep testing people, and reduce the spread by clamping down on social contact.

In fact, Rossman still thinks there's a chance that we could control the epidemic before we need the protection of herd immunity. "China's a great example: the virus didn't create herd immunity, but they've managed to contain the outbreak and stop any new cases from spreading," he says. "If we can do it there, we can do it around the world. It'll be difficult, but I think it's possible." SF

by **JAMES LLOYD**

James is staff writer at BBC Science Focus.

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Xbox's new console boasts backwards compatibility **p41**

INNOVATIONS

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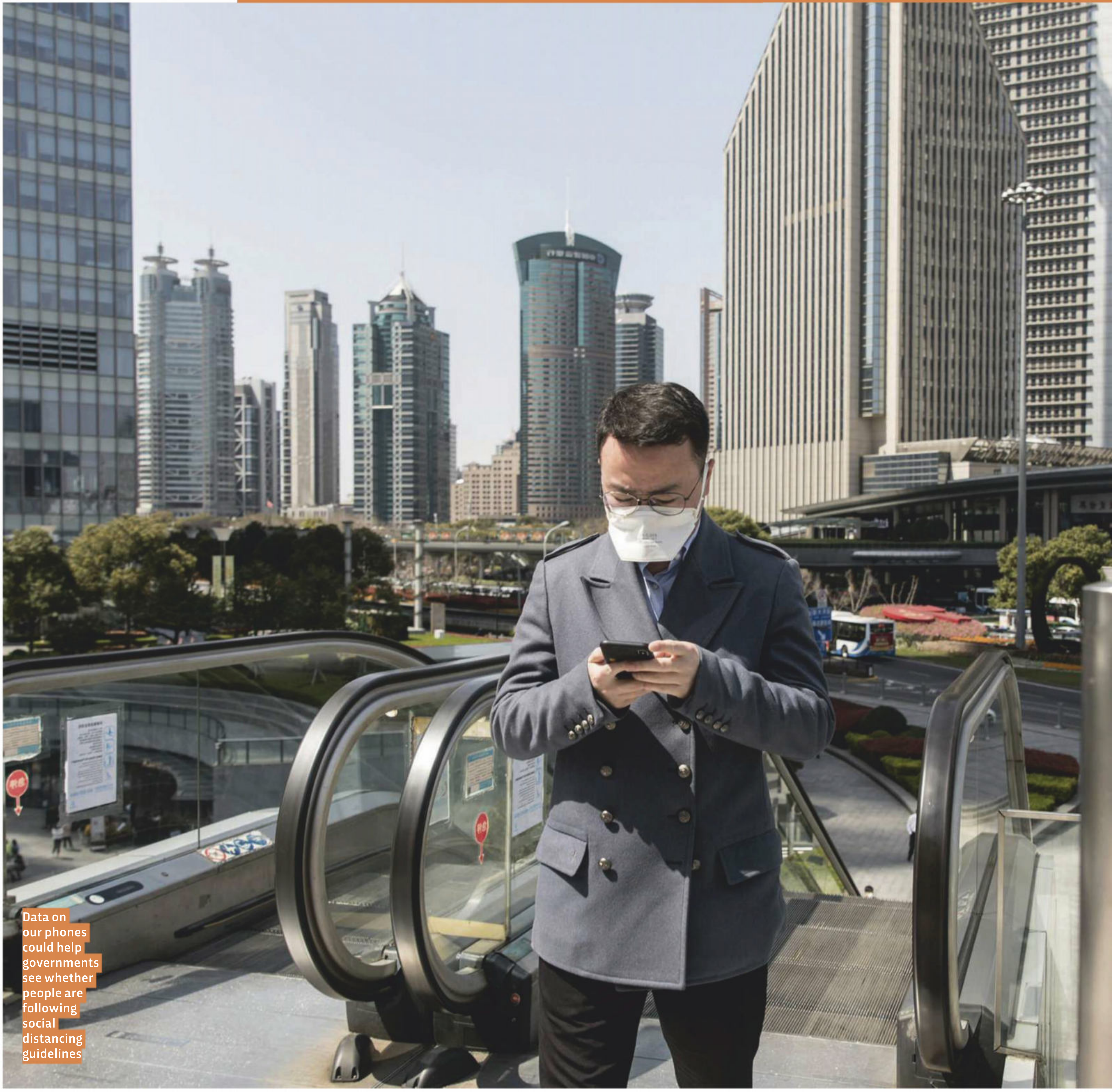


Data on our phones could help governments see whether people are following social distancing guidelines

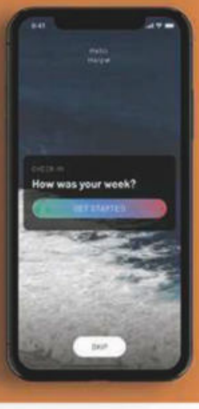
MENTAL HEALTH APPS HELP OUT

Headspace

The app has a free 'weathering the storm' section full of guided meditations, sleeps and exercises designed to help those struggling with the anxiety and isolation created by the coronavirus pandemic.

Sanvello

This app is dedicated to providing mental health care where doctors can't. It includes guided meditations, coping tools, assessments and peer support. It's free during the COVID-19 crisis.



Calm

The team behind this app have pulled together a page of resources to help people find their calm in the midst of the pandemic. In particular, their sleep range will help you drift off, crisis or not.

Calm
Daily Calm

CORONAVIRUS

Big tech takes on the pandemic

Google and Facebook could use the data they collect to track how coronavirus spreads

Both Google and Facebook are reported to be talking with governments about how to use the location data they collect from our phones to help track the spread of coronavirus across the UK, US, and presumably other countries too.

If you've never checked your privacy settings on Google or Facebook, then the chances are that both are gathering large amounts of surprisingly accurate data on your movements. Taken across a population, this information can paint an unprecedented picture of how people are gathering and moving, and therefore how the virus might spreading. The work is in its early stages, according to an anonymous source speaking to *The Washington Post*. Both companies have confirmed they've spoken with government officials but stress they haven't handed over any private data.

Governments are becoming increasingly desperate to slow the spread of coronavirus before it overwhelms hospitals. And this tool could let officials find out whether the public is observing the social distancing guidelines suggested to stem the outbreak.

The big tech companies want to anonymise the data before analysing trends that might emerge. And Google is already investigating whether data gathered from Google Maps could provide insights in the same way it already does to tell users when a shop or restaurant's peak hours are.

In the UK, the mobile phone network O2 is currently working with the government to see whether they could use cellular data to generate heat maps, which could reveal whether people really are social distancing. Meanwhile, the travel-planning app Citymapper has added a mobility index feature which takes the data it collects to analyse how much the people in a city are moving compared to usual. On Saturday 21 March, London users were moving at 23 per cent of the usual rate, while Italian cities like Milan were hovering around the 4 per cent mark. Critics of this kind of data-sharing are asking for more transparency on how the data is being anonymised.

> "IN SPAIN, POLICE HAVE TURNED TO DRONES TO HELP THEM YELL AT PEOPLE STILL ON THE STREETS"

Meanwhile WhatsApp, the messaging app, is in talks with the NHS to set up a chatbot that will help people get basic information about the pandemic. This follows a similar service set up by the World Health Organization.

Elsewhere in the world, tech's being used in increasingly inventive ways to encourage us to stay home. A security company in Austin, Texas, says it can train thermal cameras to spot people with fevers at supermarkets, hospitals and government buildings. In Spain, police have turned to drones to help them yell at people still on the streets after government advice to stay home. The country is now officially on lockdown.

Coronavirus COVID-19 Gl...
ORTH
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↓ Tech giants are using data on our movements to track how COVID-19 might spread

GETTY IMAGES X2

INTERVIEW

Are the MP3's days numbered?

At the Bristol Hi-Fi Show earlier this year, one announcement stood out. French music-streaming service Qobuz was ditching MP3 and making its high resolution (hi-res) audio streaming cheaper. It's the first streaming service to drop formats that compromise on quality. We caught up with **Benoit Rebus**, head of partnerships at Qobuz, to find out whether MP3 was on its way out…

Why make the change?

We [Qobuz] have been around in the UK since 2014. At the time we launched, we only had CD quality. Later on, we introduced studio quality. Our pricing plans and packages diversified over the years, but now we want to simplify our service and make it clear what we're about.

There's no longer an entry-level service for MP3s, but you can switch to CD or MP3 if you are in the middle of the desert and still want music.

As 4G becomes ubiquitous, you can literally stream hi-res audio in the high street, so the loss of MP3 will become a non-subject, technologically speaking. Now that speed and space are no longer a concern, why is there even MP3? The only reason MP3 stays is because of the pricing policy of the labels. The quality of audio they sell is linked to a certain price, so when that eventually falls, MP3 will disappear.

So will the price of hi-res audio come down as the demand goes up?

Yes. First we had to prove that were was demand. MP3 is 20 years old now. It was necessary when it came out, but for some reason we still stick with it. Compared to MP3, the best hi-res files are 20 times better in terms of information.

So now the biggest bottleneck in terms of audio quality is how people are connecting to their systems?

Yes. This is why we do a lot of educational work. We have knowledgeable customers, but if you don't know, you don't know. We've met people with £20,000 music systems, who can't understand why their system doesn't sound as good as it did in the store – when they're using Bluetooth. Bluetooth isn't a high-bandwidth way to send your music to your sound system. People don't realise that if they have a good system, then they ought to be using a dedicated music streamer.

What should someone do if they want to upgrade their system to keep up?

Don't ditch your speakers. Because they might still be great, especially if you bought them 20 years ago. You just need a Chromecast dongle to upgrade them – in the same way that you might improve an old TV. The only missing part that our customer needs is the streamer. Think of the streamer as a CD player but fully remoted by the smartphone. In the short term, the first piece to put money in is the streamer.

If I'm happy with MP3, why should I care?

The ear is super-lazy, so if what you feed it is poor, the ear will be happy with that, and eventually your hearing capability will reduce. It's like living in the dark, things will be much, much clearer once you see the light.

GETTY IMAGES, MARKUS NASS

Encore!

Artists turn to streaming platforms to make up for cancelled concerts

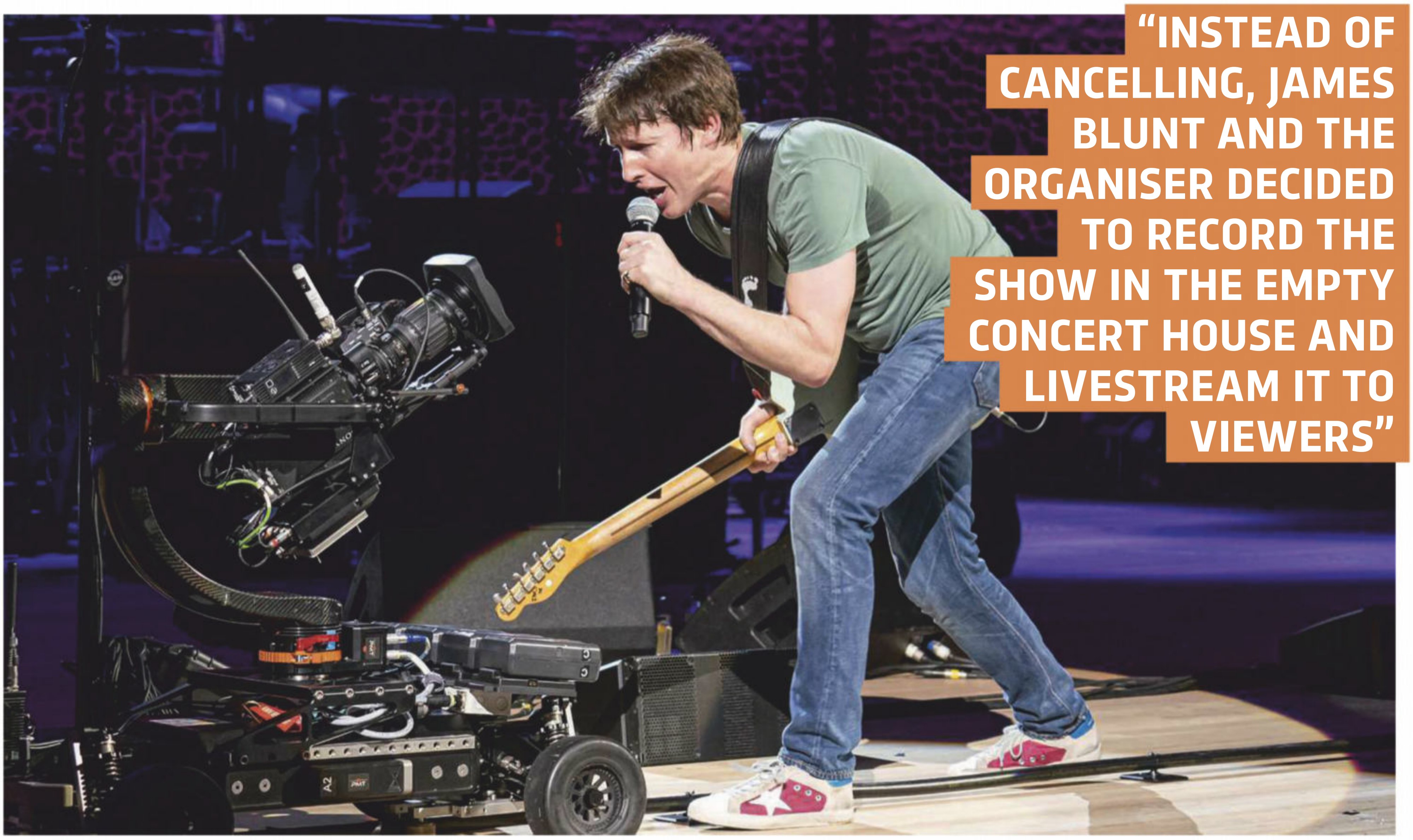
The 50th Glastonbury Festival, the Eurovision Song Contest and The Rolling Stones' tour dates are just a few musical casualties to the coronavirus pandemic. Large gatherings have been postponed or cancelled entirely to try to stop the spread, but some musicians aren't letting the lack of a physical audience prevent a performance.

Singer James Blunt – of *You're Beautiful* fame, that one song we all hate but can't help singing along to – was booked to perform in Hamburg in March, to a crowd of more than 2,000 people. Instead of cancelling, Blunt and the organiser, MagentaMusik360, decided to record the show in the empty Elbphilharmonie concert house and then livestream it to viewers from all around the world.

Other musicians are opting to stream instead of suspend, such as New York's Metropolitan Opera. Unfortunately for performers, livestreaming usually means making content free.

To combat this, some performers are turning to digital video streaming platform Twitch. Created with gamers in mind, Twitch allows users to upload live content and encourages viewers to respond in real time to what they're watching. Musicians such as Marc Rebillet and Ducky are making use of Twitch's subscription model, so fans can set up small monthly payments or one-off donations to support artists.

It seems most of the big names, though, are heading to where the Gen Zs reside: Instagram and TikTok. A campaign called Together, At Home, launched by the World Health Organization and activism movement Global Citizen, has prompted 30-minute Instagram Live sessions from artists such as John Legend, Niall Horan and Coldplay's Chris Martin. Martin, who founded Global Citizen's annual music festival, started off the series by telling fans: "The right thing to be doing is staying home... and not buying too much toilet paper."



> "INSTEAD OF CANCELLING, JAMES BLUNT AND THE ORGANISER DECIDED TO RECORD THE SHOW IN THE EMPTY CONCERT HOUSE AND LIVESTREAM IT TO VIEWERS"

On test: desktop monitors

For the foreseeable future, many of us will be working from home. Here's our pick of displays that will soothe your weary eyes...

Best for... photography and other professionals

← **Dell U2720Q,** £628.80, dell.com

This professional grade monitor from Dell is an unassuming workhorse. It's fitted with a special anti-glare coating and is remarkably clear from a wide range of viewing angles. These features, paired with a soft brightness, made the screen exceptionally easy on the eyes. At 27 inches it's at the smaller end of what's necessary for 4K, but the display is remarkably crisp. Wildlife photography especially felt rich in detail, picking up on the diverse hues of green and blue in a photo of a kingfisher. It leaves the factory fully calibrated too, so you can get straight to work. The design allows for height, swivel and pivot adjustments, with a slim frame and a minimal footprint. There's every port you could hope for at the back, including 90W USB-C that will quickly charge your laptop, and share displays with just one cable.

Best for... engineers, designers and video editors

← **BenQ PD3220U**, £1,059, benq.eu

For those of you who think that you can never have enough screen, this BenQ model is a brilliant option. 4K resolution can feel a little unnecessary on smaller screens, but on this 32-inch model, the finer detail and scale makes images sing. It's easy to set up, and looks immaculate out of the box – some high-end monitors we've tested in the past can require fiddly calibration. Photos appear rich and vibrant, with chasms of contrast between dark and light. Photos of coral reefs and landscapes practically leap off the screen. The ergonomics are effortless. The stand, though bulky, lets you adjust the height with a single finger, and allows for simple tilt and swivel adjustments. The elegant frame also disguises the pudgy side profile. There are ports galore, including a vital USB-C socket. One for high-end professionals.

Best for... the space starved

← **Samsung Space Monitor 4K,** from £359, samsung.com

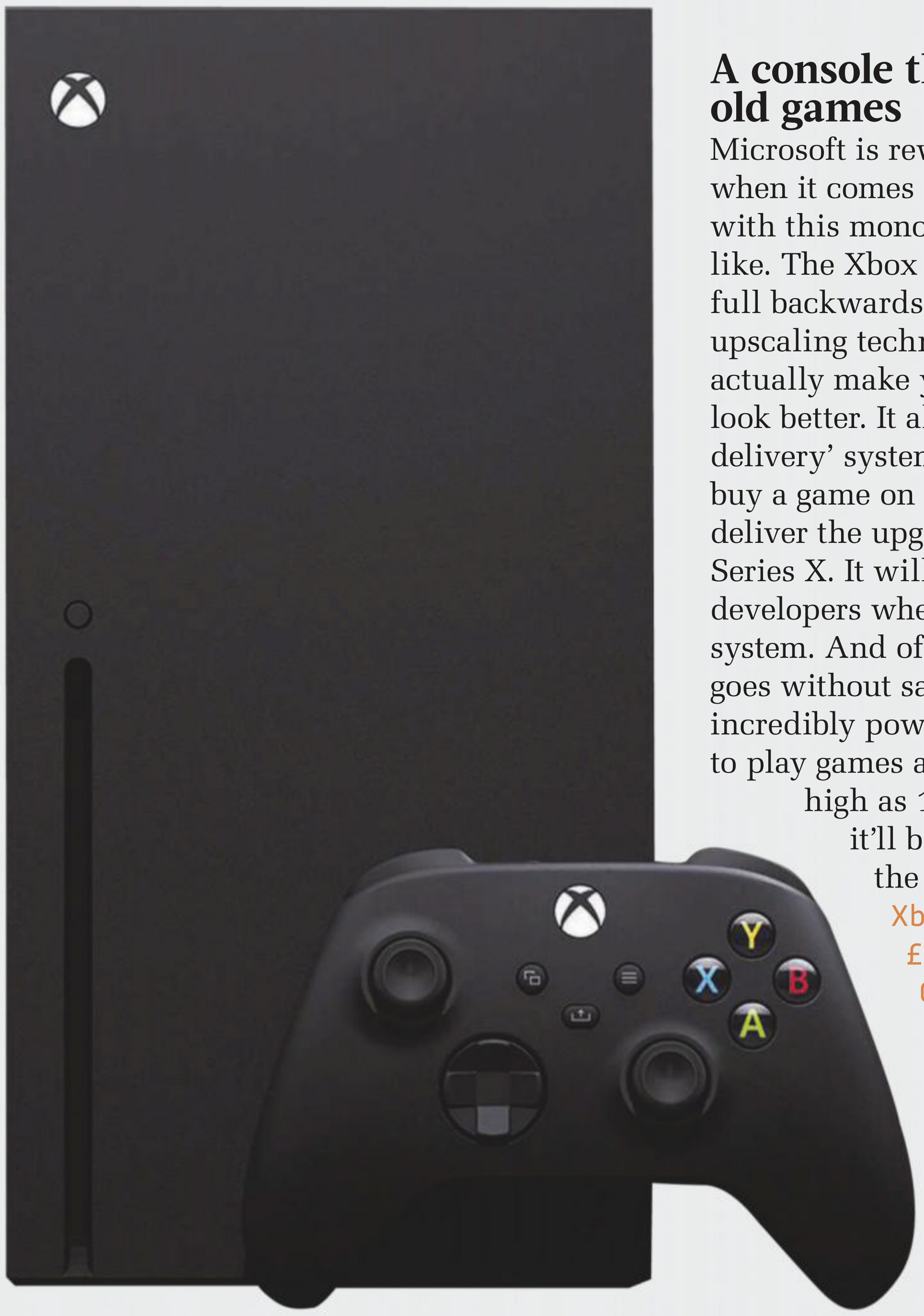
This screen (with a 27-inch and 32-inch options) is a game-changer. The monitor sits on an arm with a clamp at its base which can fix it to the side of your desk, letting you reclaim some precious workspace. Wires neatly slot into the stand too and follow it down to the edge of the table. You can't adjust the monitor's height, but you can pull the monitor down towards the desk on its double-hinged arm until it's flush with the surface. It's so smart, that we wish it was a touchscreen so we could use it as a giant tablet. The clever design means there's some small concessions elsewhere. The display performance isn't as pixel-perfect as the others tested, but more than sufficient for the majority of uses. Unfortunately, there's no USB-C port on offer. But if you suddenly find yourself making an office in the living room, it does a great job at tilting the balance towards home rather than office.

Ideas we like...

A tablet that can replace my laptop

Apple's new iPad Pro blurs the line between laptop and tablet. The Magic Keyboard now comes with a trackpad at the bottom, and the hardware inside is virtually on a par with the tech inside a Macbook Air. The operating system will still be iOS (rather than OSX, which you usually find on Macs), but increasingly apps are becoming just as sophisticated as full-scale Mac software. It now includes a LiDAR scanner, which means it can scan and see the world around it, empowering some incredible augmented reality experiences.

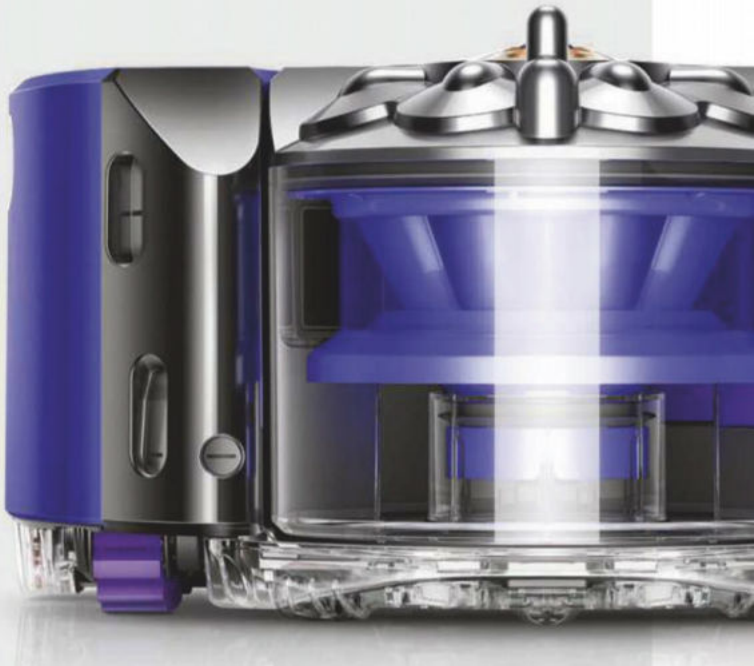
iPad Pro 2020, from £769, apple.com



A console that likes your old games

Microsoft is rewriting the book when it comes to console design with this monolith that we rather like. The Xbox Series X will boast full backwards compatibility, with upscaling technology that will actually make your old games look better. It also offers a 'smart delivery' system, which means if you buy a game on Xbox One, it'll also deliver the upgraded version to your Series X. It will be up to individual developers whether they use the system. And of course, it almost goes without saying, but it will be incredibly powerful. It will be able to play games at 4K, at frames rate as high as 120fps. Microsoft says it'll be twice as powerful as the current Xbox One X.

Xbox Series X,
£TBC, xbox.com
Out November 2020



A smarter robot vacuum cleaner

Dyson has given its robo-cleaner some new brains. More precisely, they've put a quad-core processor and 10GB of storage onboard, 20x what its predecessor the Eye was equipped with. The extra computing oomph means that it should get better at navigating and charting the ins and outs of your house. Once the Heurist has mapped your home, you can tell it to clean only specific areas via your home or identify no-go areas full of precious cables.

Dyson Heurist, £799, dyson.com

HUBBLE'S HIDDEN GEMS

IN THE 30 YEARS SINCE HUBBLE'S LAUNCH, THIS ICONIC SPACE TELESCOPE HAS BEEN REVEALING THE WONDERS OF THE UNIVERSE WHILE BUILDING UP A LIBRARY OF SOME OF THE MOST SHINING SIGHTS IN THE COSMOS

WORDS: DR ELIZABETH PEARSON

IMAGES: NASA/HUBBLE SPACE TELESCOPE HERITAGE TEAM

LIFTING THE VEIL

←

VEIL NEBULA

Stars that reach a violent end and explode in a supernova will often leave behind a scar on the sky – a brightly coloured cloud of gas, known as a supernova remnant. The Veil Nebula is one such remnant, stretching out over 110 light-years.

Hubble took a look at the Veil Nebula back in 1997, only to return in 2015 when this image was taken. In the intervening years, astronauts had visited Hubble using the Space Shuttle and upgraded the main widefield and planetary camera for a second time. The improved resolution revealed the nebula's delicate gas filaments in a new level of detail.

The original supernova appears to have exploded just 8,000 years ago (practically yesterday in astronomy terms) and is still expanding. In the 18 years between the first and second images, the cloud has grown in size. Astronomers have been able to pick out these changes, helping to understand how such nebulae evolve. ▶

DUST BUSTER

←

PISMIS 24

Pismis 24 is just one cluster of stars in a large nebula, NGC 6357. The entire region is home to many young and growing stars, aka protostars. These grow up in thick dust clouds, which hide them from telescopes that can only view the Universe at visible wavelengths.

"Hubble can be used for UV, visible and some infrared observations. These panchromatic capabilities are incredibly useful for studying everything from Solar System activity to distant galaxies," explains Jennifer Wiseman, senior project scientist for the Hubble Space Telescope.

Here, Hubble has been able to pierce through the dust, creating a window into where infant stars are born. It was thought the mass of the cluster's brightest star, Pismis 24-1, was around 300 times that of the Sun, making it the heaviest in the Galaxy. However, Hubble puts it at a far more modest 100 solar masses.

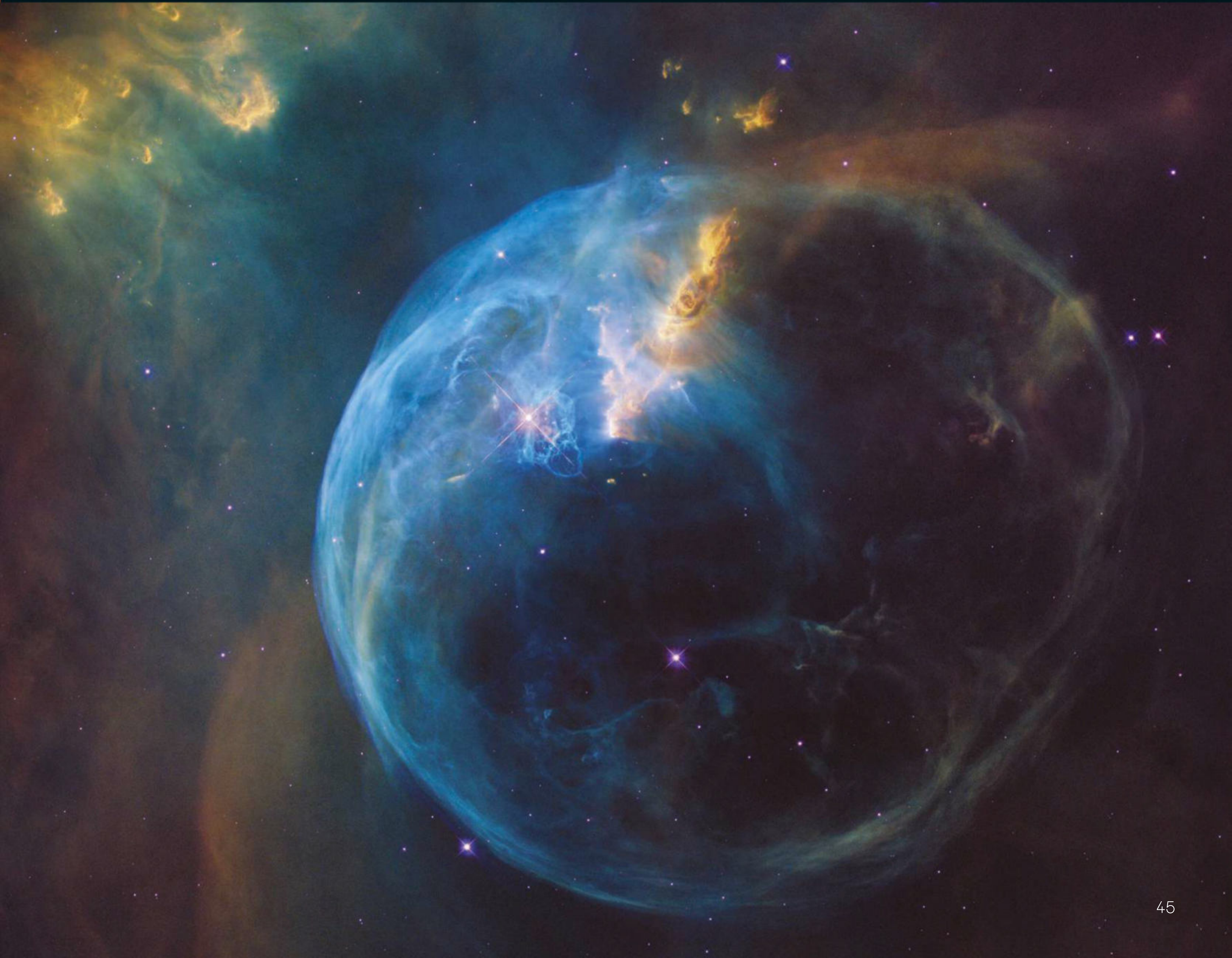
STELLAR SHOCKWAVE

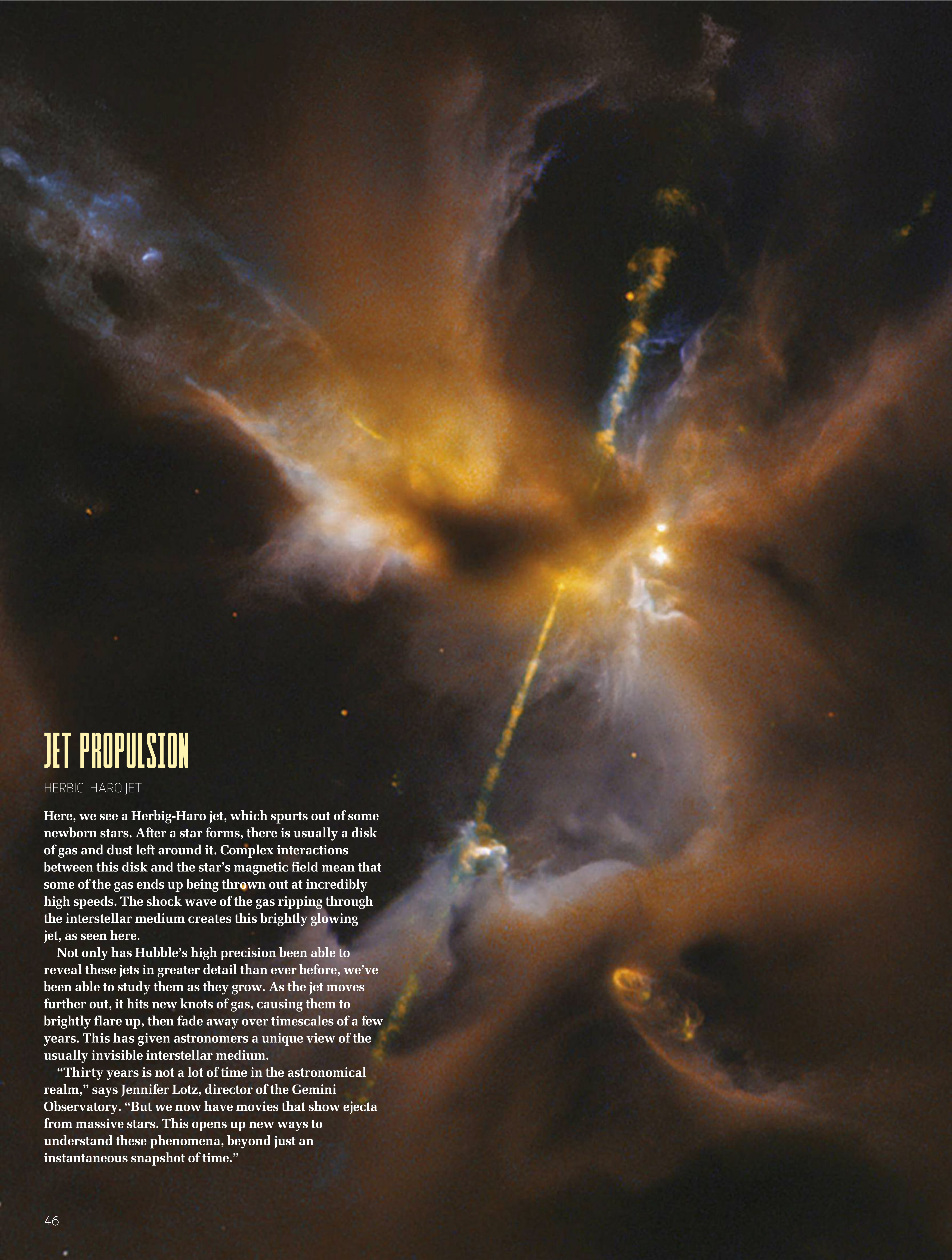
↓

BUBBLE NEBULA

Also known as NGC 7635, the Bubble Nebula was created by a petulant star, around 45 times the mass of our Sun, throwing out its gas, or stellar wind. The gas is travelling at around 6.5 million kilometres per hour, and as the resulting cloud expands out, it slams into the surrounding interstellar medium – this is the gas which fills the space between the stars – creating a shock wave. The advancing wave causes the regions it passes through to heat up and glow, producing the bright bubble that gives this nebula its name.

The bubble is lopsided, however, with the star located in the top left. The interstellar medium in this region is much cooler, and therefore denser, making it harder for the gas to expand in that direction. ►





JET PROPULSION

HERBIG-HARO JET

Here, we see a Herbig-Haro jet, which spurts out of some newborn stars. After a star forms, there is usually a disk of gas and dust left around it. Complex interactions between this disk and the star's magnetic field mean that some of the gas ends up being thrown out at incredibly high speeds. The shock wave of the gas ripping through the interstellar medium creates this brightly glowing jet, as seen here.

Not only has Hubble's high precision been able to reveal these jets in greater detail than ever before, we've been able to study them as they grow. As the jet moves further out, it hits new knots of gas, causing them to brightly flare up, then fade away over timescales of a few years. This has given astronomers a unique view of the usually invisible interstellar medium.

"Thirty years is not a lot of time in the astronomical realm," says Jennifer Lotz, director of the Gemini Observatory. "But we now have movies that show ejecta from massive stars. This opens up new ways to understand these phenomena, beyond just an instantaneous snapshot of time."

HOT STUFF

→

NGC 5033

Spiral galaxy NGC 5033 is much like our own. It's around the same size, about 100,000 light-years across, and at its core is a supermassive black hole, weighing anywhere between 10 million and a few billion solar masses.

Unlike the Milky Way, however, NGC 5033's black hole isn't docile. Instead, it's surrounded by a swirling disk of gas and dust, moving so rapidly that it superheats. This makes it glow brightly, forming what's known as an active galactic nucleus.
Over the years, Hubble has found hundreds of supermassive black holes by looking at the motion of dust in the centres of galaxies. If the material is moving rapidly, there must be a black hole holding it in place or it would speed off into the rest of the galaxy.

"Hubble observations of the centres of massive galaxies showed that supermassive black holes lived in the centres of almost every galaxy," says Lotz. "We now believe that supermassive black holes play a critical role in shaping galaxies."

THE LONELY STAR

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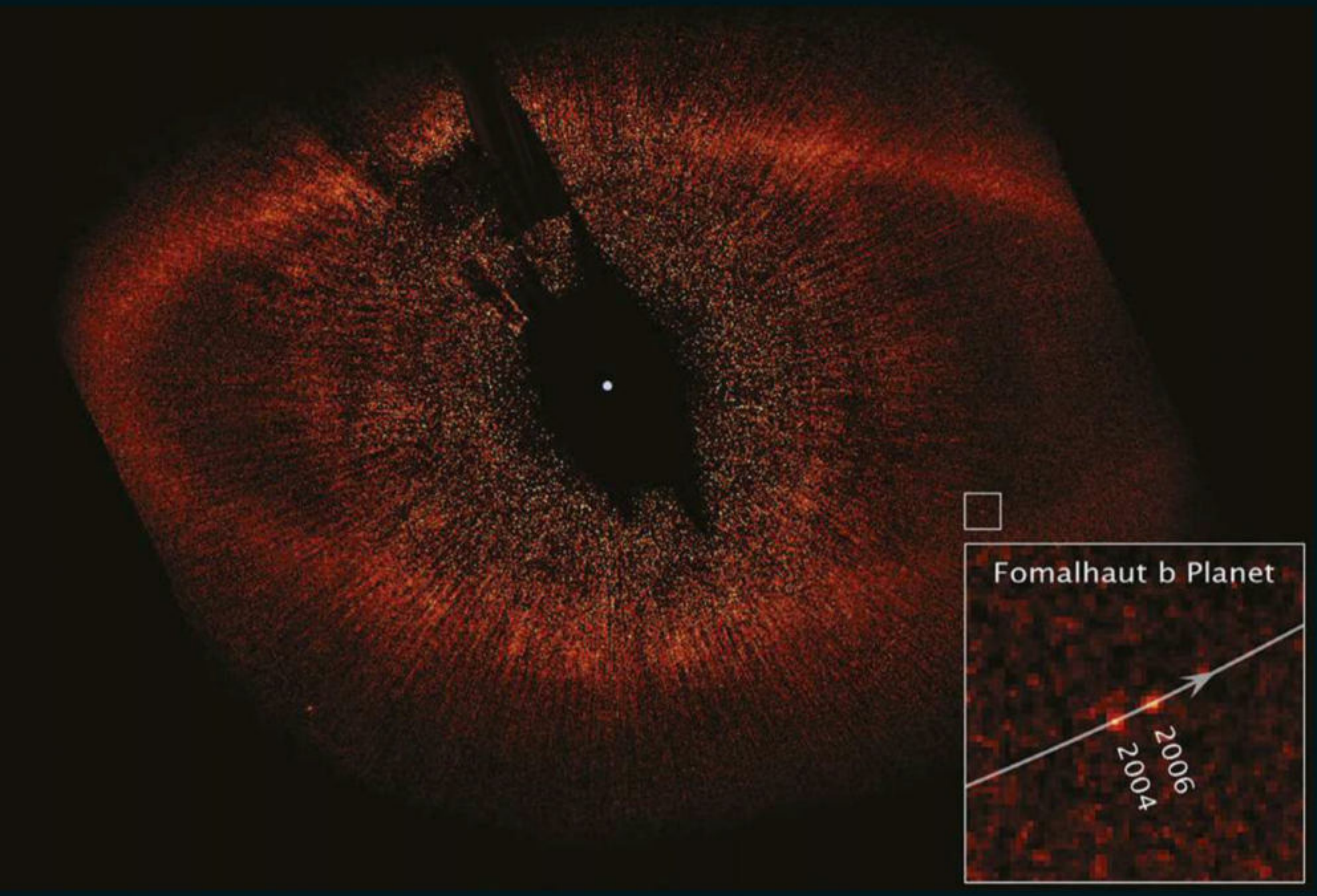
FOMALHAUT

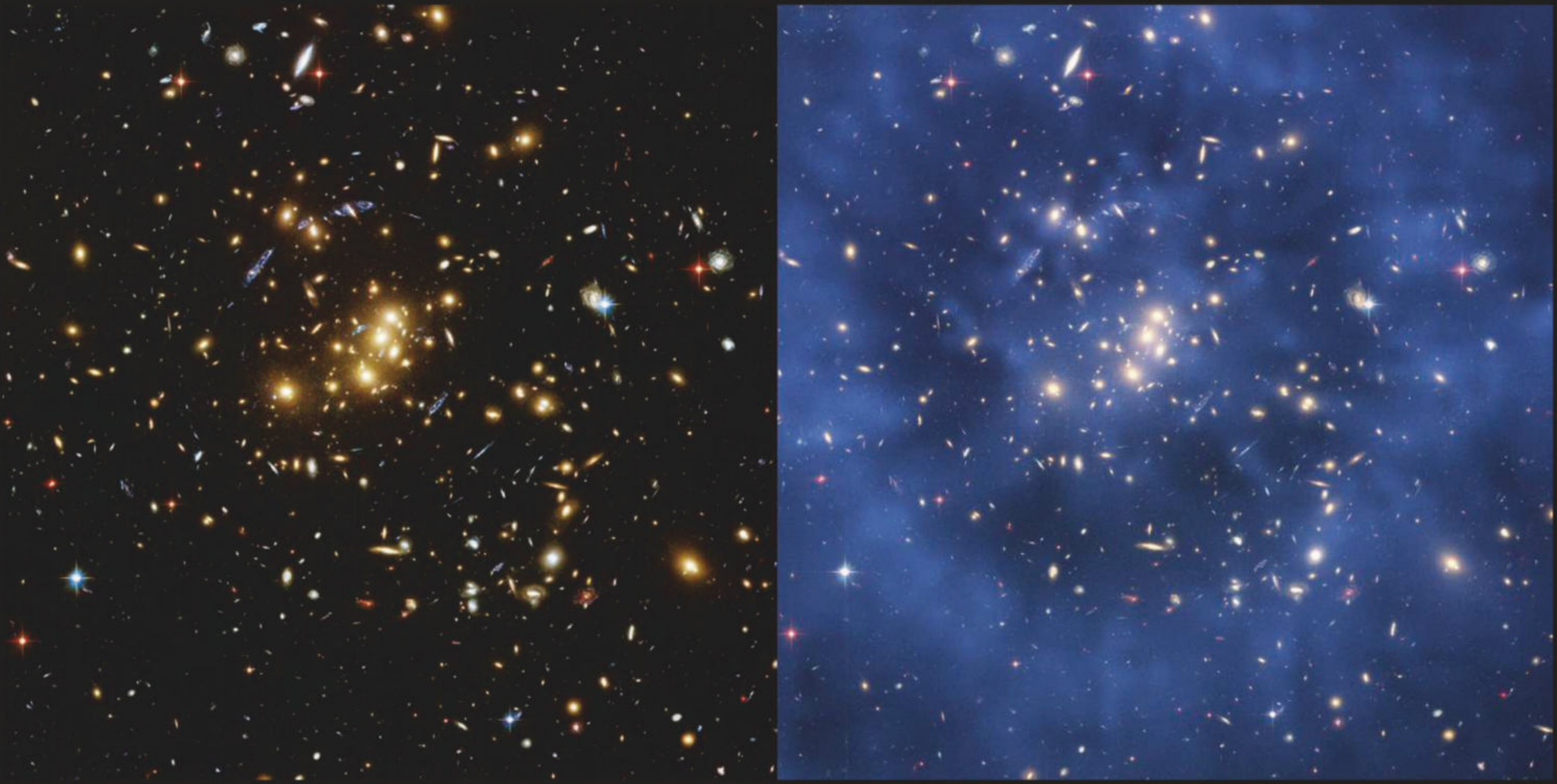


Before Hubble launched, the only planets we knew about were those in our Solar System. Today, we know of thousands of exoplanets orbiting other stars.

"Hubble has been right at the forefront of studying exoplanets," says Wiseman. "It's not a great instrument for finding them – the field of view is too small and it only has a small window for searching the vast sky – but what it can be used to do, is carry out intimately detailed follow-up observations."

One rare case where Hubble did find a planet was around the star Fomalhaut. The star is surrounded by a ring of dust stretching out to around 20 billion kilometres – that's three times further out than Pluto.

Such rings are usually created by planets shepherding dust into a specific orbit. Hoping to track down this world, Hubble repeatedly took images of the system over a period of several years. Comparing the images, astronomers found a bright dot slowly moving around the disk. It was a planet, and the first one ever directly imaged in visible light. ➲



COSMIC LENS

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GRAVITATIONAL LENSING

Galaxy clusters are one of the most massive objects in the Universe. They are so heavy that they warp the fabric of space-time, to the point that light gets bent as it passes by. Under the right conditions, this bending can act as a lens, magnifying galaxies located billions of light-years behind them, an effect known as gravitational lensing.

In the left-hand picture above, you can see several bright blue galaxies which have been lensed, though the process has distorted them into curved arc shapes. Such images are vital in tracking one of the most mysterious substances in the Universe, dark matter. "Most of the matter in a cluster is dark matter," explains Wiseman. "We don't know what dark matter is, but through Hubble's observations of lensing we can tell how it's distributed and the history of how dark matter evolved throughout the history of the Universe."

After studying the pattern of distorted galaxies, astronomers have created a map of dark matter within this cluster, shown in the right-hand image, in blue.

by **DR ELIZABETH PEARSON** *(@EzzyP)*
Elizabeth is a space journalist and news editor at BBC Sky At Night magazine.

WHEN GALAXIES COLLIDE

→

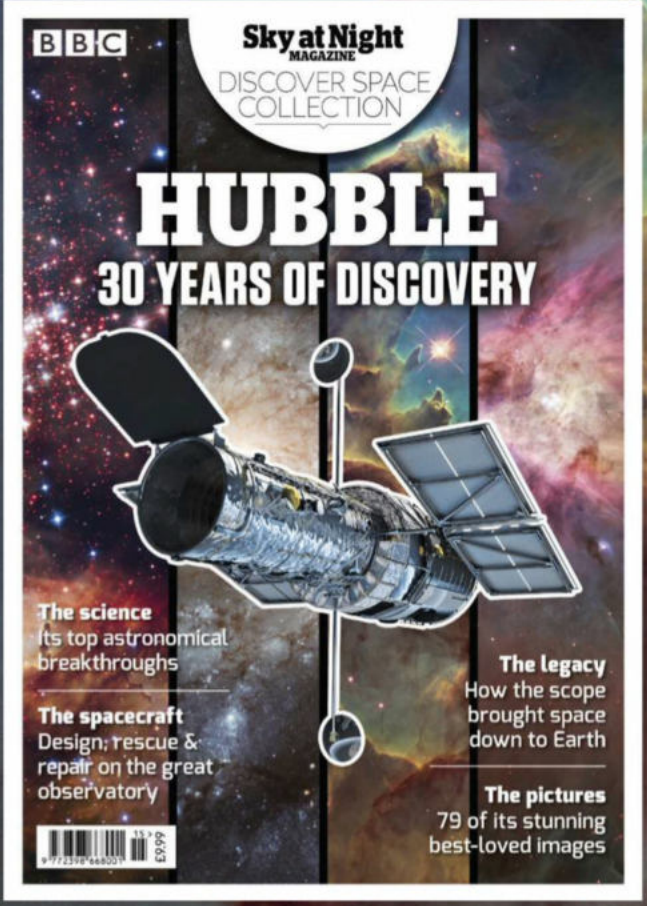
GALAXIES COLLIDING

Two galaxies colliding into each other sounds like it should be hazardous, if not fatal, to the objects involved. In reality, it is the main way these stellar collectives grow and evolve. When they crash together, or even just pass close by, the resulting chaos stirs up the gas within them, creating knots of material which go on to form stellar nurseries.

Here, we see two separate galaxies that have recently passed close enough that they've pulled each other's spiral arms out of shape. Hubble's ultraviolet cameras have been able to pick out regions where hot, young stars are busily forming. These are the bright blue clumps clustered around the galaxies' distorted arms, where the interaction would create the most turbulence.

Hubble's unparalleled sharpness and ability to see in the ultraviolet is one of the key ways in which it differs from its Earth-bound counterparts. Our atmosphere soaks up most of the ultraviolet radiation that arrives at our planet, and so Hubble's view above the atmosphere gives us a unique view of the Universe at these wavelengths of light. SF

SPECIAL EDITION



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WHAT HUBBLE TAUGHT US

Hubble launched in 1990 and over the last 30 years it has given us a new perspective on our Solar System, the worlds beyond our cosmic neighbourhood, and even the fabric that holds it all together

by **DR ELIZABETH PEARSON**

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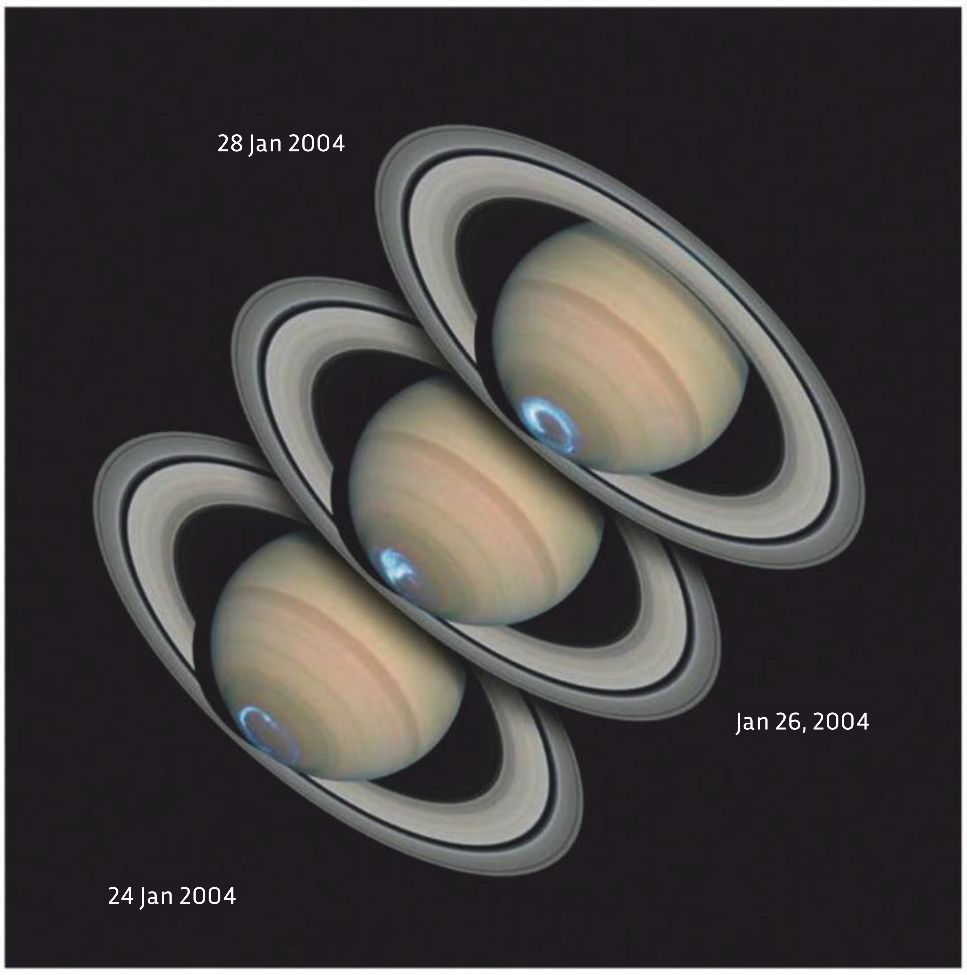
NASA

PART ONE

A NEW PERSPECTIVE ON THE PLANETS

Hubble has changed the way we see our cosmic neighbours, as it works with other probes to bring our Solar System into focus



ABOVE These images reveal how much Saturn's aurorae change in the space of just a few days

The Solar System is our cosmic back garden. It should be one of the best-known parts of our corner of the Universe. Yet when Hubble launched in 1990 our planetary neighbourhood was still deeply shrouded in mystery. Looking up from Earth, the ever-shifting atmosphere blurred our view of the planets, making it difficult to see their features. Above the turbulent air, Hubble could watch these worlds in peace and has been doing so for the last three decades.

This long life has been one of Hubble's greatest assets, making it possible to reveal the weather and climate patterns of changing seasons on our sister worlds as they make their journeys around the Sun. The Hubble science team has taken advantage of this unique long view by undertaking a project called the Outer Planet Atmospheres Legacy (OPAL).

"OPAL employs Hubble to look every few months at Jupiter, Saturn, Uranus and Neptune to see if they've changed," says Jennifer Wiseman, Hubble's senior project scientist. "Through OPAL we've learned how the Great Red Spot on Jupiter, a giant storm, is actually shrinking and changing colour over time. We see new storms cropping up, and we see them coming and going on some of the other outer planets too. Studying the changing nature of the planets in our Solar System is something that Hubble is enabling us to do through both its clarity of imagery and its longevity."

MISSION SUPPORT

Of course, Hubble hasn't been the only one watching the planets over the years. Since its launch, dozens of missions have been sent across our Solar System and Hubble is often called upon to supply much needed context. When Cassini arrived at Saturn in 2004, it could only see small parts of the planet at a time. Hubble, however, was able to take in the entire planet. While this was at a much lower resolution, the telescope was able to track storms and auroral activity to help planetary scientists understand the data Cassini was sending back.

"This profoundly improves the science return from any of these particular missions, compared to them operating on their own," says Wiseman.

Mars has been another target of Hubble's attentions as it works in concert with the armada of spacecraft on and around the Red Planet. The telescope has helped to track the huge dust storms which blow across the planet every Martian year. Once again, this gives a global appraisal of the storm's progress while the in-situ probes note localised changes such as temperature and pressure.

It's not just during missions that Hubble offers support, however. For almost every planetary mission of the last 30 years, Hubble has been used to scout the way before the spacecraft even reached its target.

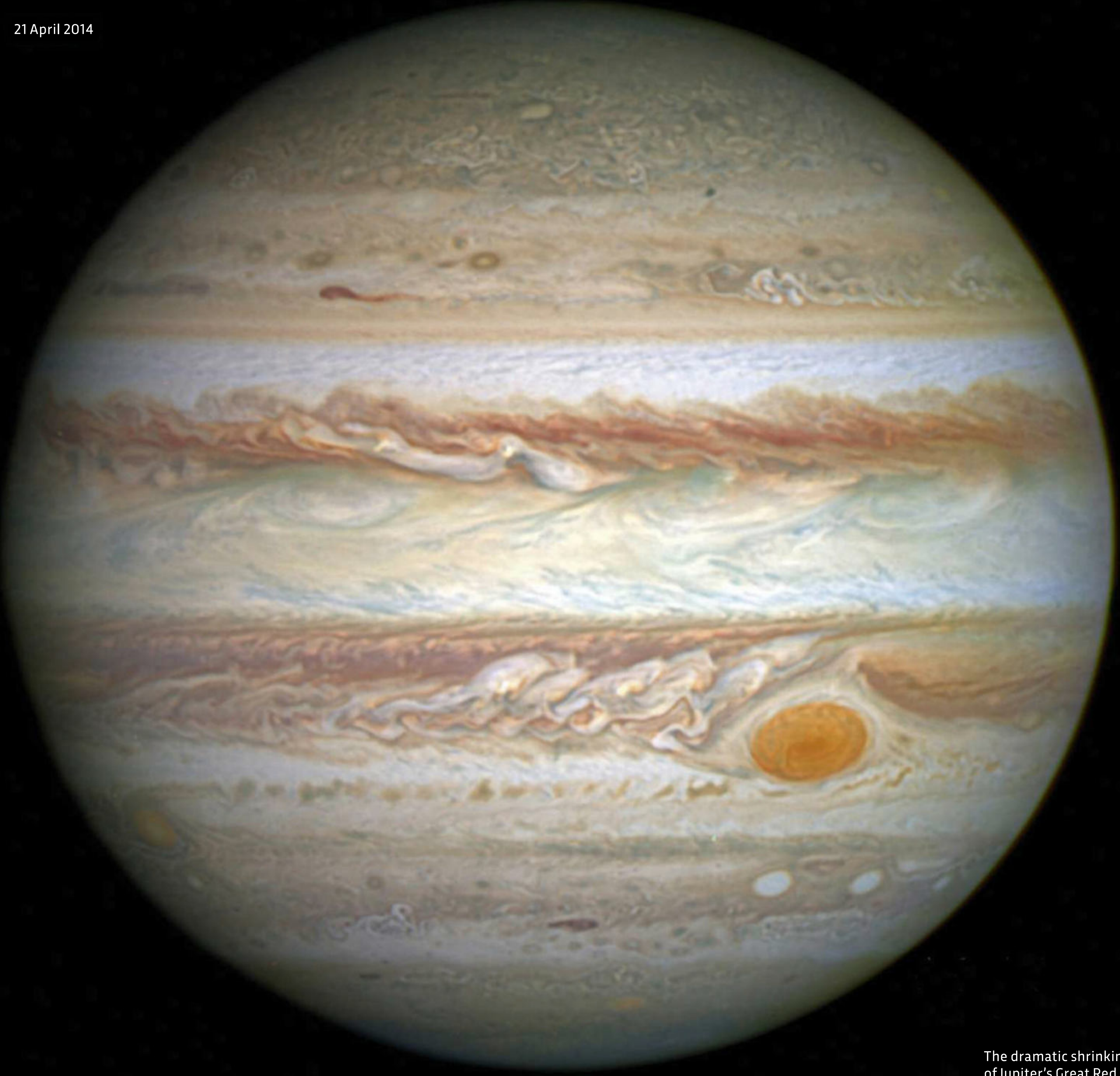
"Hubble was used to help in planning the New Horizons mission which passed by the Pluto system in 2015," says Wiseman. "The space telescope's observations helped inform the planning of that probe's trajectory and get it safely to Pluto."

EYE IN THE SKY

Before New Horizons' approach, the operations team feared flying into an unseen moon or other obstacle around the dwarf planet, and so used Hubble to search for potential hazards. It was during this campaign that Hubble revealed the presence of a pair of moons, Nix and Styx, allowing New Horizons to plot a trajectory which avoided them.

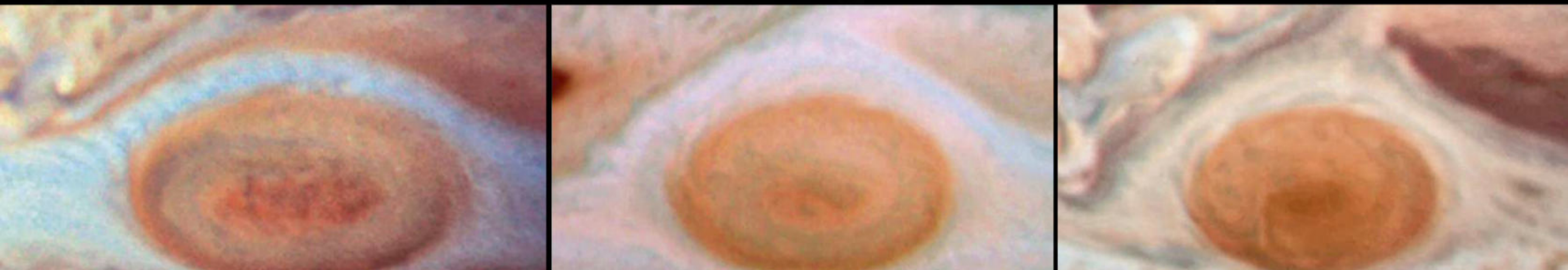
Hubble offers another perspective that many of these planetary spacecraft lack – the ability to observe in the infrared and ultraviolet. For the Juno mission at Jupiter this capability

NASA/ESA/A. SIMON/GODDARD SPACE FLIGHT CENTER, NASA X4



21 April 2014

The dramatic shrinking of Jupiter's Great Red Spot is captured in 1995, 2009 and 2014



1995

2009

2014

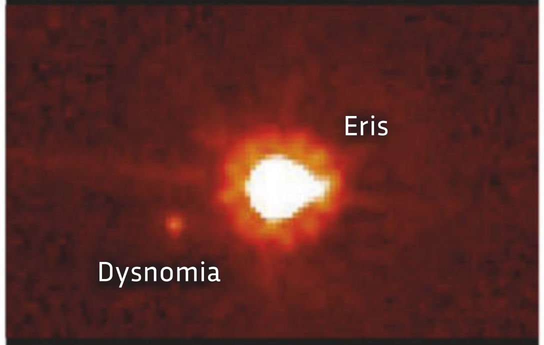
HUBBLE'S TOP 3

SOLAR SYSTEM MOMENTS

Hubble has made some of the most definitive planetary discoveries in recent times

SEASONS ON URANUS

When Voyager 2 flew past Uranus in 1986, the ice giant appeared to be a placid marble with little weather. But Hubble has revealed the planet is now more active, suggesting that seasons have changed. It's found several dark patches, which are believed to be storms blowing up on the planet.



DEMOTING PLUTO

In 2005, Mike Brown uncovered a large body in the outer Kuiper Belt, now known as Eris. It was over 2,300km wide, around the same size as Pluto. The discovery triggered a debate, and ultimately led to Pluto being demoted to dwarf planet.

JUPITER'S AURORAE

In 1997, Hubble was upgraded with a more sensitive Space Telescope Imaging Spectrograph, which revealed Jupiter's ultraviolet aurorae. Astronomers found it formed curtains just like Earth's, extending several hundred kilometres over the surface.

LEFT Comet Shoemaker-Levy 9 colliding with Jupiter

provides extra resolution to its observations of the gas giant's magnetic field. Juno's instrument payload cannot register the high-energy, ultraviolet aurorae these fields create but Hubble can. By combining the two, astronomers are given a far more complete view of the planet, allowing them to work out even more detail about the magnetic fields of this giant world.

"We've also used Hubble to study the nature of some of the moons of these planets, and we've revealed some quite unexpected results," says Wiseman. "For example, when Hubble observed some of the moons of Jupiter, we found that both Ganymede and Europa showed signs of liquid water oceans under an ice-crusted outer layer."

In 2016, Hubble helped to confirm the presence of water outside the moons as well, when it discovered there was a plume of water ice fountaining high over Europa, forced up from an underwater ocean through the cracks in the moon's crust.

But some of Hubble's greatest triumphs have come from those times when the Solar System threw out something unexpected.

INTERSTELLAR VISITORS

"One of Hubble's most famous detections happened early on in its career, when comet Shoemaker-Levy 9 unexpectedly collided with Jupiter in 1994," says Wiseman. As soon as astronomers realised the comet would collide, they called on the Hubble team to make sure the telescope was watching.

"That incredible set of images completely transformed our understanding of how dynamic the Solar System is," says Wiseman. "We realised how vulnerable planets actually are to being impacted by objects and debris whizzing around."

Hubble has observed many comets and asteroids since then, but in the last few years a new category of transient space rock has been added to the line-up – interstellar visitors. In 2017, asteroid 'Oumuamua was seen speeding through our Solar System, having been thrown out of another star system. Then in late 2019, comet 2I/Borisov followed suit. In both cases, Hubble was on hand to capture the objects on camera as they flew by.

Since Hubble launched in 1990 it has revolutionised our knowledge of the worlds in our back garden. The telescope has been a key tool in helping to unravel their mysteries, but there are still plenty of secrets hidden in the shadows of these distant worlds. As long as it's still running, astronomers will be calling on Hubble to help drag them into the light.

NASA/KSC, NASA/HUBBLE SPACE TELESCOPE X3, NASA/ESA/HUBBLE AND THE HUBBLE HERITAGE TEAM

PART TWO

THE MILKY WAY

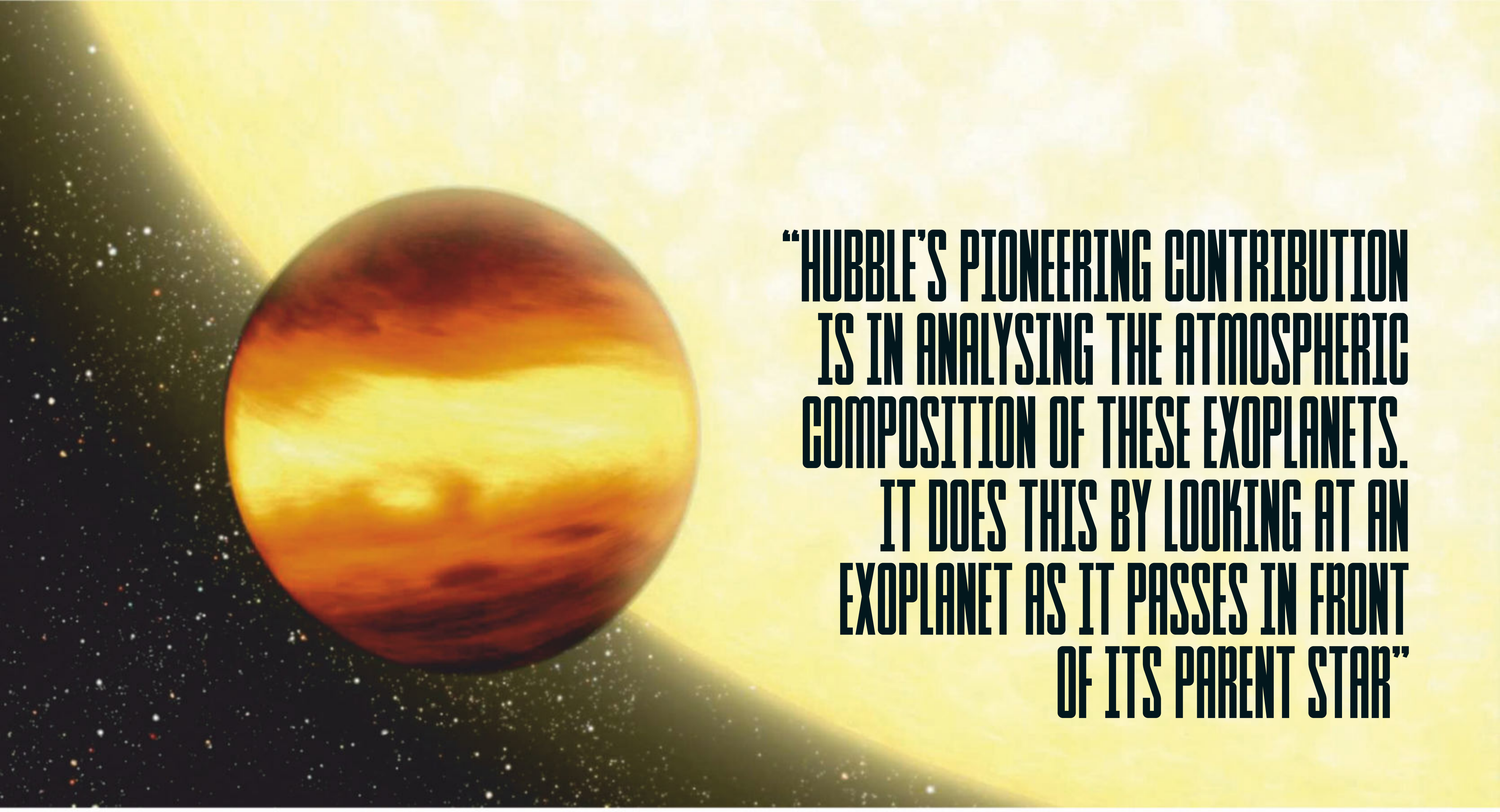
The story of the stars is written across our Galaxy, and Hubble has helped us read it

The Milky Way is home to some incredible sights. From the dusty beauty of stellar nurseries to the colourful detritus left after a star explodes, Hubble has helped to reveal the beauty of our Galaxy. Yet these images are not only stunning to look at. To an astronomer's eye, these photographs tell the story of a star's life.

The tale begins soon after Hubble launched 30 years ago, when it first turned its eye towards some of the clouds of dust dotted throughout our Galaxy. Astronomers believed that these were stellar nurseries, the places where every star in our night sky began its life. The most famous image of one of these birthing grounds (and perhaps Hubble's most famous shot ever) is of the Eagle Nebula, M16 (pictured here). The image, taken in 1995, is better known as the Pillars of Creation, inside which new stars are starting to form.

"We see these pillar-like structures in many Hubble observations of these nebulae," says Jennifer Wiseman, Hubble's senior project scientist. "The wind from massive newly formed stars carves out these structures around the bigger clumps in the gas that is left behind."

This image of the Pillars of Creation in the Eagle Nebula was taken by Hubble's newer Wide Field Camera 3 in 2014. To give an idea of scale, the towering pillars are about five light-years tall



> “HUBBLE’S PIONEERING CONTRIBUTION IS IN ANALYSING THE ATMOSPHERIC COMPOSITION OF THESE EXOPLANETS. IT DOES THIS BY LOOKING AT AN EXOPLANET AS IT PASSES IN FRONT OF ITS PARENT STAR”

ABOVE To date, more than 4,000 exoplanets have been discovered

By studying the shapes of these cloud formations, astronomers were able to unpick these critical early stages in a star’s life. Partly, they’ve done this by watching how the clouds have changed over the last 20 years. In 2015, a new version of the same image revealed that one of the jets within the cloud had grown by almost 100 billion kilometres, demonstrating just how dynamic these regions truly are.

Even more excitingly, when Hubble took a closer look at some of the Orion Nebula’s infant stars, it found several of them had disks of swirling dust – a sign they were entering the next chapter of their lives and forming planets. As a star grows, it often forms a protoplanetary disk of dust around it. Over time this debris clumps together, gradually growing in size to eventually become a planetary system.

OBSERVING ALIEN WORLDS

Studying these disks is a vital step in one of the fastest growing study areas of astronomy: exoplanets, the planets that exist in other solar systems.

“When Hubble was designed there was no concept that it would be used to study planets outside our Solar System. We didn’t know of exoplanets at that time,” says Wiseman.

Since the first exoplanets were discovered back in the 1990s, over 4,000 worlds have been confirmed; a number which grows every day. Tracking these planets down requires looking at large areas of sky for a long time. With its narrow field of view and the high-demand for its time, Hubble is ill-equipped for this task. But it can take a deeper look at planets other observatories have already discovered.

“Hubble’s pioneering contribution is in analysing the atmospheric composition of these exoplanets,” says Wiseman. “It does this by looking at an exoplanet as it passes in front of its parent star. During that transit, light from the star passes through the outer regions of the atmosphere. Some of that light is absorbed by the atmosphere of that planet and that signature is still in the light received by Hubble.”

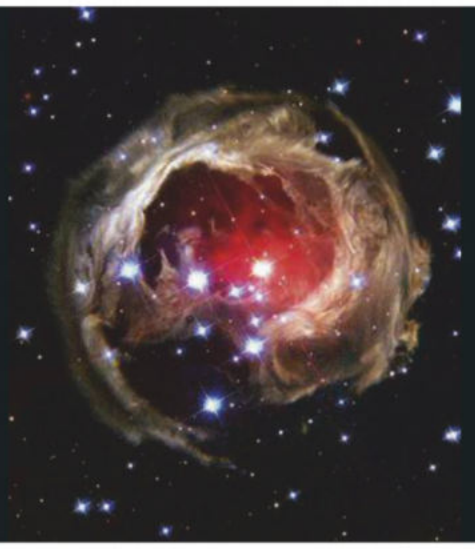
By pulling this signature apart, astronomers are able to detect several key elements and molecules within a planet’s atmosphere. One important molecule that Hubble is especially suited to look for is water. On Earth, wherever you find water you find life. So astronomers are keen to pin down how many other planets are as wet as ours in the hope of predicting where else in our Galaxy we might find life.

Hubble’s resolution is so great that it can even create a basic outline of the weather patterns on a planet’s surface. When the telescope

HUBBLE’S TOP 3

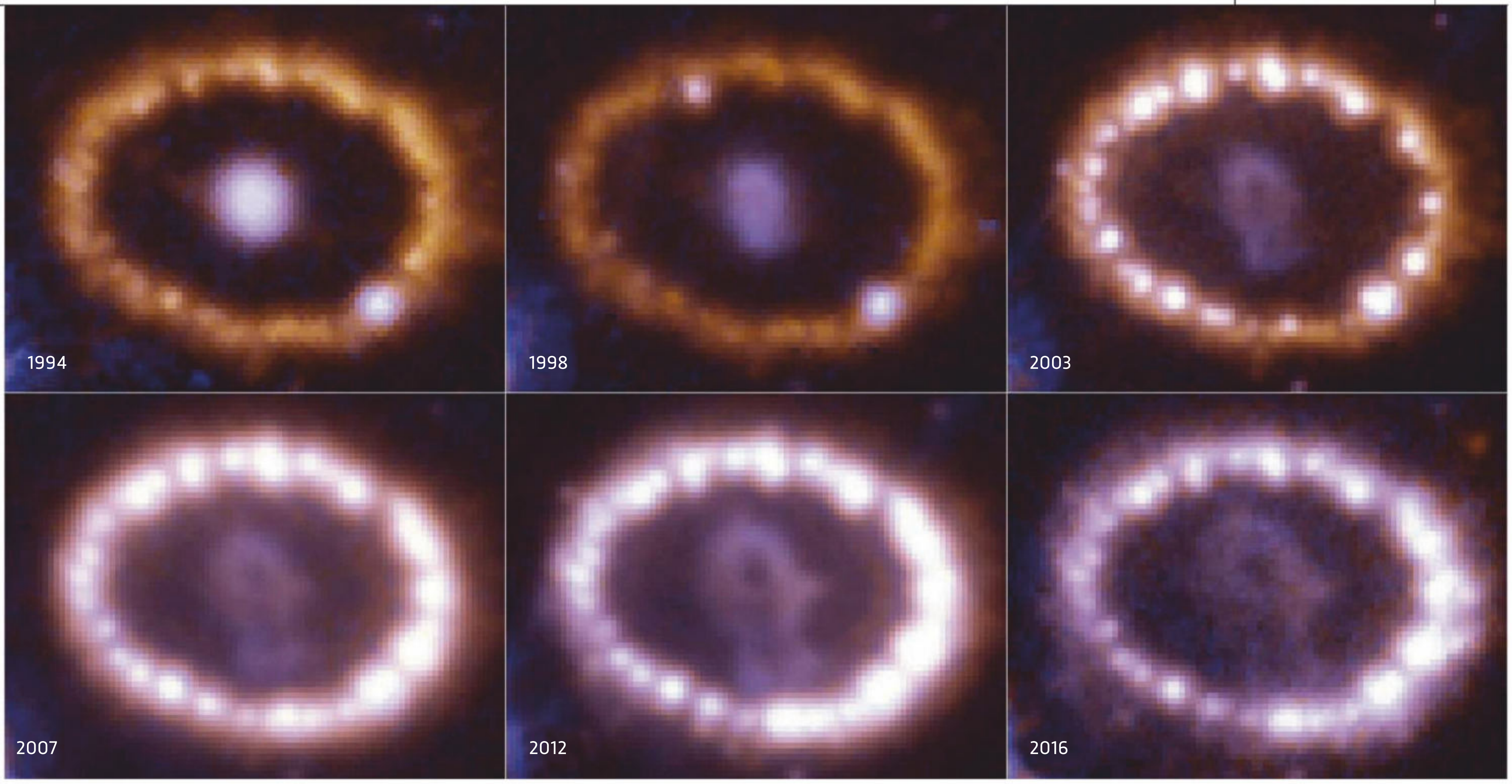
DISCOVERIES IN THE MILKY WAY

Hubble has peered into the heart of the spiral galaxy we call home to reveal some amazing discoveries



V838 MONOCEROTIS

In 2002, the red star V838 Monocerotis flared up, temporarily shining 600,000 times brighter than the Sun. No one is sure why, but over the last 20 years the light from this flash has advanced outwards, illuminating the surrounding gas. Hubble has allowed astronomers to map this expanding ‘light echo’.



ABOVE The evolution of the supernova 1987A between 1994 and 2016, as captured by Hubble telescope

NASA/THE HUBBLE HERITAGE TEAM, ESA/HUBBLE/M. KORNMESSER, NASA/ESA/P KALAS, NASA/JPL-CALTECH, NASA/ESA/R KIRSHNER,P CHALLIS /HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

looked at tidally locked WASP-43b, where one side of the planet always faces its sun, it was able to pick out the hot patches on its eternally sunlit side. Using this, astronomers were able to predict how the winds of the planet blow between the day and night sides.

But just as Hubble reveals the origins of stars and planets, it has also turned to the pages of their final act. When a star's nuclear fuel is expended, they die. If the star is large enough, this death is an explosive affair known as a supernova. Once again, Hubble's power lies not in first detecting these cosmic flashes but in taking a look at them afterwards.

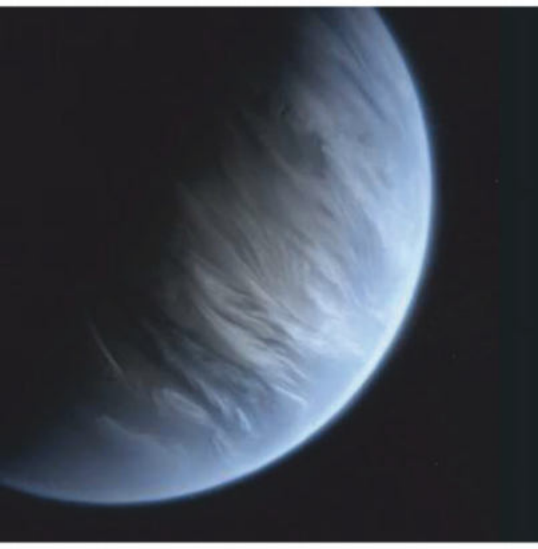
SUPERNOVA STUDIES

Throughout their lifetimes, stars transform the hydrogen created in the Big Bang into helium and other heavier elements. When the star goes supernova, it throws these elements outward. As the hot cloud of gas crashes into the surrounding medium it creates an advancing shock wave, lit from within by a white dwarf – a small hot star, all that remains of the exploded stellar body. As these gas bubbles look fuzzy and spherical from Earth, they were initially mistaken for planets, leading them to be called 'planetary nebula', despite having nothing to do with planets.

In 1987, just before Hubble launched, a supernova detonated in the Milky Way's companion galaxy, the Large Magellanic Cloud. Over the years, Hubble has watched as the ring of gas from this explosion has moved out and expanded into the interstellar medium – the gas which fills the space between the stars.

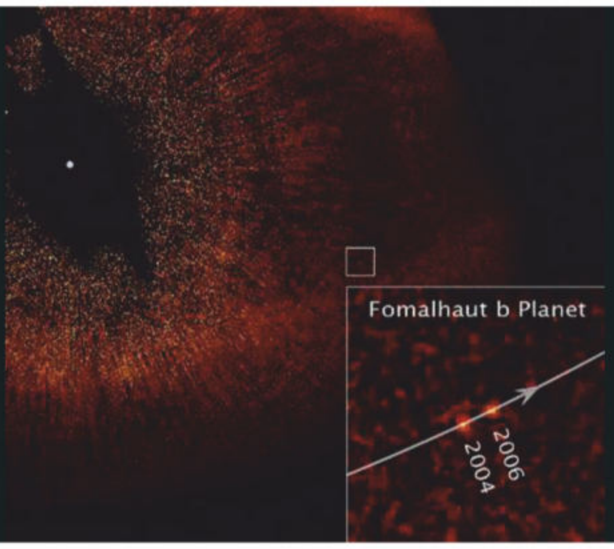
The turbulence caused by these shock waves can, in time, cause the interstellar medium to gather together. This new cloud, enriched with all the elements the dying star threw out into the Universe, then goes on to form stellar nurseries, bringing the cosmic tale of stellar life back around to its beginning again.

The Milky Way is a dynamic place, filled with stars being born, forming planets and then dying, only for their remains to provide the fuel to repeat the cycle again. And Hubble has been critical to observing every step of this incredible process. ➜



WATER IN THE HABITABLE ZONE

Astronomers have found many exoplanets in the so-called 'habitable zone' – the region around a star where temperatures allow liquid water to pool on the surface, potentially allowing life to evolve. In 2019, Hubble was able to discover water vapour in the atmosphere above exoplanet K2-18b for the first time.



FIRST DIRECT IMAGE OF A PLANET

In 2004, Hubble imaged the disk of dust, measuring 34.5 billion kilometres in diameter, surrounding the star Formalhaut. The disk has a sharp inner edge, suggesting it is being shepherded by a planet. Over the years, Hubble watched a bright point of light move around the star. It was an orbiting alien world – the first ever to have been imaged directly.

PART THREE

A VIEW ACROSS TIME

Hubble has helped to peer back across the aeons of time and shown that the Universe is growing at an ever faster rate

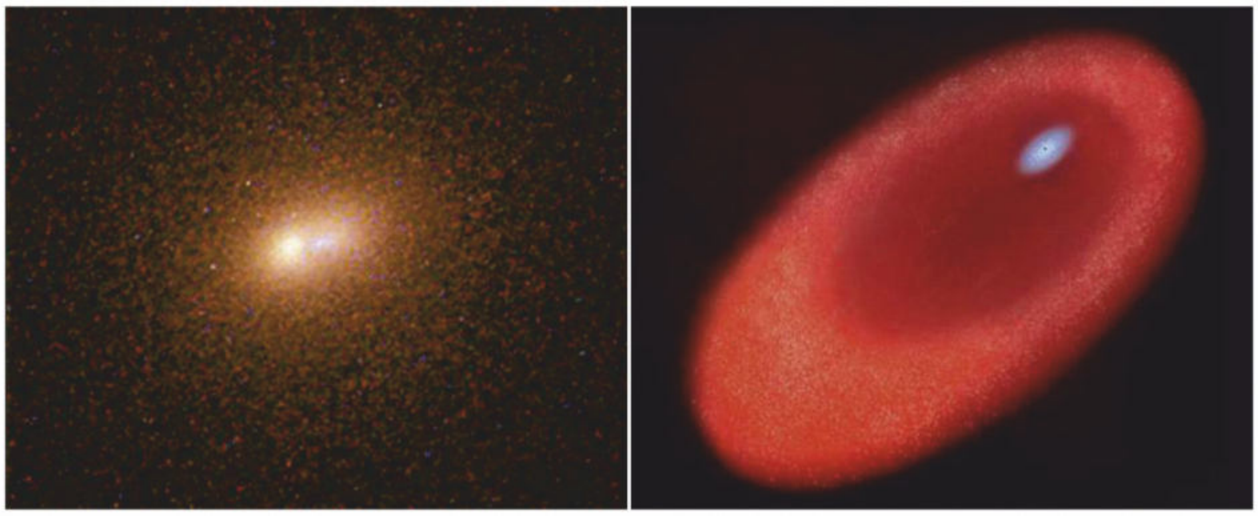
Hubble's high resolution, large aperture and extreme precision means that it can pull photons out of the darkest reaches of the Universe, looking further back than any visual telescope that came before it. As the light from these distant galaxies and stars has taken billions of years to cross the void, we see them as they were millennia ago, all the way back to the earliest days of the Universe.

"We can compare the nature of the most distant galaxies to those we see closer to us in space and time, to see if they are different. And, in fact, they are," says Jennifer Wiseman, Hubble's senior project scientist. "I think Hubble's most profound contribution has been revealing to us how the Universe has changed over time."

Nowhere is this capability better showcased than in the Hubble Deep Field images. The first of these was taken in 1995, when the telescope took a 100-hour long exposure – many times longer than normal – of an apparently blank stretch of sky. At the time, some astronomers argued the image was a waste of precious Hubble time, but when the image was put together, they were swiftly proved wrong.

This first image contained almost 3,000 galaxies, some dating back to when the first stars were forming. These appeared to be smaller and more irregular than those in the present day, demonstrating that galaxies do change over time.

RIGHT In 1996, Hubble captured this Deep Field image, which shows a view stretching to the Universe's visible horizon



BELOW The core of the Andromeda Galaxy (left) photographed by Hubble, and an artist's impression of it (right). Both images show a disk of stars (in blue) that were used as evidence for a huge black hole

SUPERNOVAE CLUES

While Hubble's keen eye has been able to make out these distant galaxies, it has also been key in working out exactly how far away these remote stellar collectives are.

"Hubble observes the Type Ia supernovae that astronomers use to gauge the distance to far away galaxies," says Wiseman.

These Type Ia supernovae always explode with the same brightness, so by measuring their apparent brightness from Earth, astronomers can work out how far away they – and the galaxy they occurred in – must be.

“HUBBLE IS BEING USED TO OBSERVE CLUSTERS OF GALAXIES TO DETECT THESE ARCS OF DISTORTED LIGHT”

R WILLIAMS/THE HUBBLE DEEP FIELD TEAM/NASA/ESA, NASA/ESA X2

Calculating these distances is a key part of one of Hubble’s main science goals – measuring the rate at which the Universe is expanding.

“Ever since Edwin Hubble took observations showing galaxies were receding a century ago, we’ve known that the Universe appears to be expanding, and that space seems to be stretching,” says Wiseman. “But measuring the actual rate of that expansion has been challenging because it requires precise distance measurements. Hubble has helped to make these observations with higher and higher precision, leading to one of its most impactful contributions – realising the Universe’s expansion is actually accelerating.”

Astronomers were surprised when two independent teams discovered this acceleration in 1998. Everyone had assumed that after the Big Bang the expansion would either slow to a stop or plateau to a steady rate. If the expansion is accelerating, then the question arises: what’s speeding it up?

“We still don’t fully understand,” says Wiseman. “It’s a very hot topic in astrophysics. We call it dark energy and Hubble has really played a key role in its study.”

Today, astronomers believe dark energy makes up around 75 per cent of the Universe. A small portion of the rest is made up of luminous matter, such as the gas and dust that glows in clouds or burns in stars. The remaining 24 per cent is dark matter, another mysterious substance which threads through our Universe, extending out between galaxies and stars.

DARK ENIGMA

This dark matter doesn’t interact with light the way normal matter does, making it completely invisible to normal telescopes. But it does interact with the visible Universe through gravity, meaning that Hubble is able to bring this ‘unseeable’ substance into the light.

“Any type of mass will distort space-time,” says Wiseman. “If you have a very large collection of mass, that distortion might actually create a phenomenon significant enough to be observed.”

This effect is known as gravitational lensing, where light from a distant galaxy is bent by the gravity of a huge object, such as a cluster of galaxies. However, the process isn’t perfect and by the time the light from the distant galaxy reaches Earth it’s usually been badly distorted.

“Hubble is being used to observe clusters of galaxies to detect these arcs of distorted ➤

HUBBLE'S TOP 3

UNIVERSE MOMENTS

Hubble has fundamentally altered our view on the largest of scales

EXTREME DEEP FIELD

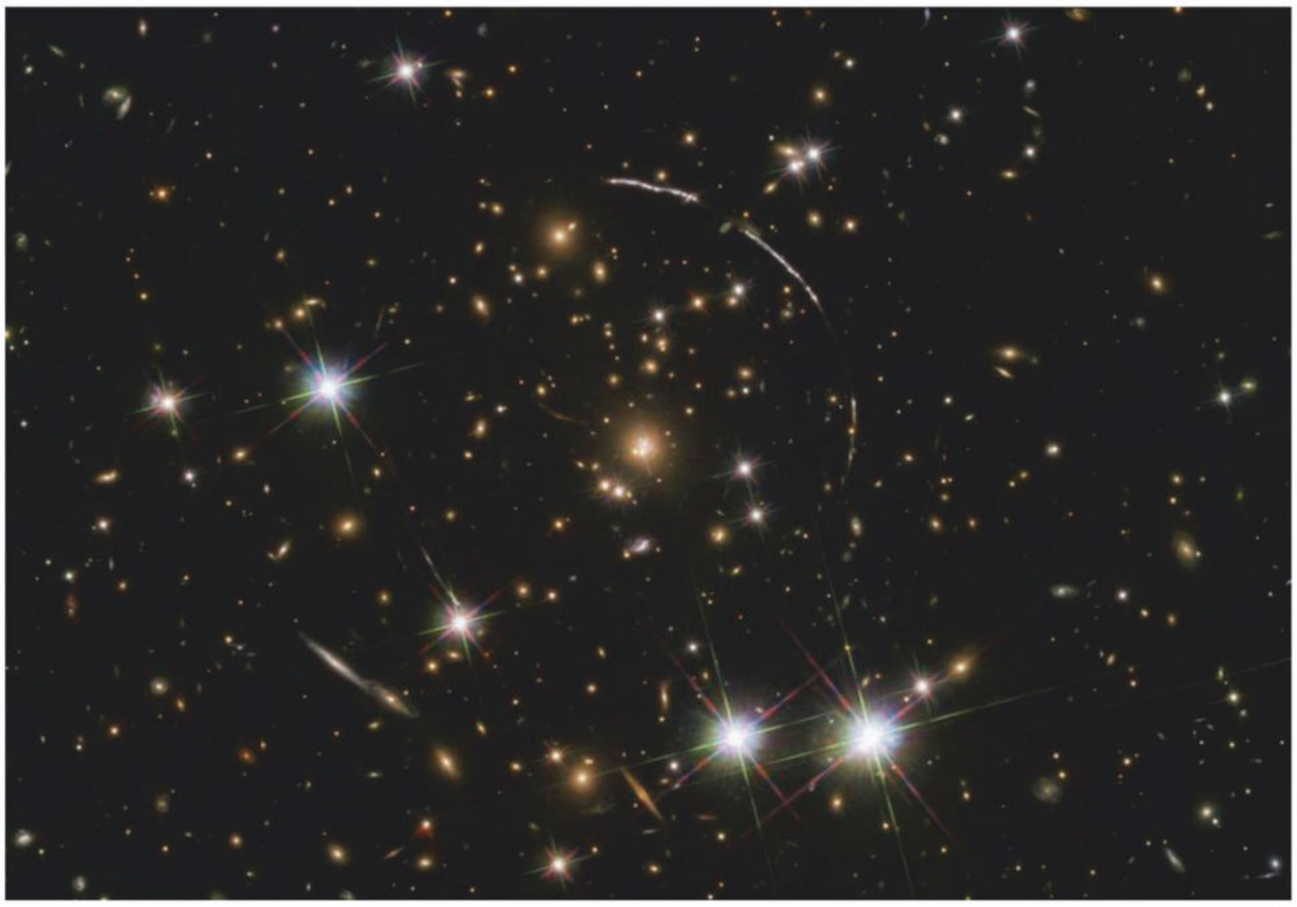
In 2012, the Hubble team released the eXtreme Deep Field. The image covered just 2x2.3 arcminutes, around 1/32,000,000ths of the sky, yet had an exposure time of around 23 days. It looks back through 13.2 billion years, showing one galaxy when it was just 450 million years old.

CONFIRMING PRIMORDIAL HELIUM

In 1995, Hubble finally confirmed the presence of primordial helium. Theory had predicted that after the Big Bang, the cooling Universe formed both helium and hydrogen, but the former had never been seen before.

GAMMA RAY BURSTS

GRBs are the most powerful explosions in the known Universe, but their origins are a mystery. In 2019, Hubble found a GRB that had come from the dense environment of a bright galaxy around five billion light-years away – a clue to the conditions that might cause a GRB.



ABOVE This image, taken by Hubble, is a good example of gravitational lensing. The massive galaxy cluster in the centre of the image is about 4.6 billion light-years away. It is surrounded by four arcs (three in the top right, one in the bottom left). Within these narrow arcs are at least 12 copies of a galaxy nicknamed the Sunburst Arc, located nearly 11 billion light-years away. Its light is being distorted into multiple images by gravitational lensing

light," says Wiseman. "By examining the gravitational lensing of the galaxy clusters we can tell something about how mass is distributed in these clusters."

Most of this mass is dark matter. By looking at how much galaxies are distorted, astronomers are able to map out how the mysterious substance is distributed throughout the Universe.

SPOTTING BLACK HOLES

Another seemingly invisible object that Hubble has helped illuminate are supermassive black holes. These dense bodies are several billion times more massive than our Sun and are thought to lie at the heart of most galaxies. Before Hubble, these black holes were entirely theoretical. The only evidence of their existence were radio observations of distant galaxies known as quasars, which contained objects around the size of the Solar System but which shone brighter than any other known thing in the Universe. Hubble was able to determine that the radio emissions were coming from the centres of the galaxies that held them, most likely from extremely hot gas that was being intensely heated as it swirled around a giant black hole.

In 1997, the Space Telescope Imaging Spectrograph was installed on Hubble. This instrument was much better at looking at the region close to a galaxy's centre, and it could make out the rapid movement of stars caught in orbit close to a black hole. The instrument soon found them, definitively proving the existence of supermassive black holes.

For the last 30 years, Hubble has helped astronomers to pull out photons from the deepest depths of space, and even illuminated places in our cosmos where no light shines, helping to reveal the Universe's darkest secrets. **SF**

by **DR ELIZABETH PEARSON** *(@EzzyP)*
Elizabeth is a space journalist and news editor at BBC Sky At Night *magazine.*

NASA/ESA/G. ILLINGWORTH/D. MAGEE, AND P. OESCH (UNIVERSITY OF CALIFORNIA/SANTA CRUZ)/R. BOUWENS (LEIDEN UNIVERSITY) AND THE HUDF09 TEAM, MALEKAS85/ISTOCK/GETTY IMAGES, NASA/ESA AND M. KORNMESSER, ESA/HUBBLE/NASA/RIVERA-THORSEN ET AL, NASA/MICHAEL SOLURI, NASA/W. HRYBYK

INTERVIEW

KEVIN HARTNETT

Hubble's science operations manager joined the team in 1997, and is responsible for overseeing scientific aspects of the space telescope's operations. With a bachelor's degree in physics and astronomy, his career began in the private industry before he started working at NASA

HOW IS HUBBLE DOING?
It's performing at the peak of its capabilities and functioning marvellously. There aren't as many available backups as there were some years ago. For instance, Hubble has six gyros to keep itself orientated, but only three are active and we need three to do our best science.

Our engineers are coming up with clever ways to combat ageing. Things dim, they fade, one side of the detector has a greater sensitivity than the other. But they've kept the observations really at the forefront of what anyone can do on the ground or in space, and that's pretty remarkable.

> "WE HAVE VERY FINE GUIDANCE SENSORS. IT'S LIKE KEEPING A LASER POINTER ON A DIME 330KM AWAY FOR 24 HOURS"

WHAT SETS HUBBLE APART?
It's a one-stop shop for very stable, high contrast imaging and spectroscopy from the near infrared wavelengths right through to the ultraviolet, with a 2.4m mirror above the atmosphere. We have very fine guidance sensors too. In layman's terms, it's like being on top of the Washington Monument in Washington, DC and keeping a laser pointer on a dime on the top of the Empire State Building in New York City 330 kilometres away for 24 hours. So once we lock on, we really lock on target.

WHAT TYPE OF RESEARCH DOES HUBBLE DO?
Solar System astronomy, galaxies, large-scale structure of the Universe, and everything in between – Hubble has made major contributions to every astronomical field. There are also legacy programmes. For instance, there's a large project right now to observe every Milky Way globular cluster. Not because someone wants to write a paper on all 150 clusters, but the data is there if someone ever does.

DOES THE OLD DATA STILL GET USED?
Oh my, yes. There's a lot of interesting science you can do with a 25-year baseline. If you've got good observations from 25 years ago, you can compare them to similar observations today. You can see jets actually moving out of the big quasar in M87. You can calculate velocities. Scientists can get a lot out of data like that.

HOW LONG DOES HUBBLE HAVE LEFT?
Hubble doesn't have a propulsion system and it is slowly falling to Earth. A report from September 2018 predicts Hubble re-entry no earlier than 2027, and the mean date is around 2038. We're very in-tune with the performance of the telescope and we're trying to pamper all of its systems, to keep it running as long as possible.

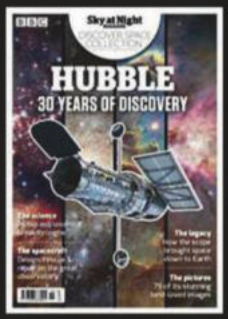
FROM THE MAKERS OF

BBC Sky at Night MAGAZINE

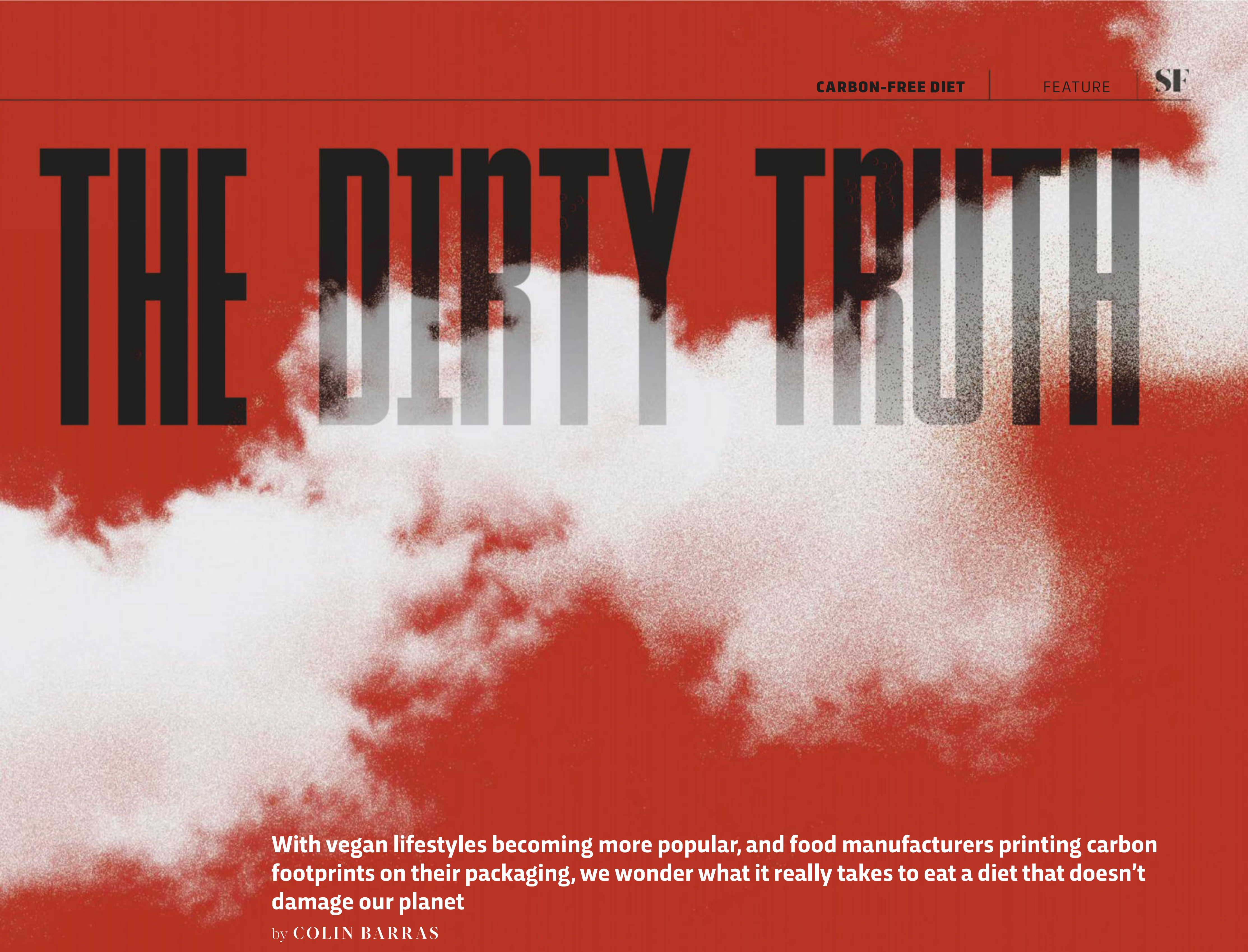
ABOVE Kevin Hartnett working in the Space Telescope Operations Control Center during Hubble's final servicing mission in 2009

DISCOVER MORE

READ
Hubble: 30 Years Of Discovery *is out now.*



EATING GREEN...



THE DIRTY TRUTH

With vegan lifestyles becoming more popular, and food manufacturers printing carbon footprints on their packaging, we wonder what it really takes to eat a diet that doesn't damage our planet

by COLIN BARRAS

ILLUSTRATION: TOM STRAW

Look at a packet of Quorn mince and you'll discover that a 75g serving contains 10.9g of protein, 3.4g of carbohydrates and 0.4g of saturated fat. Later this year, a glance at the packet will tell you something else: that producing the 75g serving released the equivalent of 0.16kg of carbon dioxide into the atmosphere.

Since 2011, Quorn Foods has been working with researchers at Sheffield Hallam University and Innovate UK, a non-departmental public body, to calculate the carbon footprint of its meatless products. Now it has had the information certified by the Carbon Trust, and plans to add it to product packets later this year. Doing so should, says Quorn Foods, "better [inform] people who want to understand the environmental impact of the foods they buy". But will the move really help Britons understand and lower their dietary carbon footprint – and how close can we get to a zero-carbon diet?

Judging by the volume of media coverage on the subject, consumers are increasingly interested in cutting their carbon footprints. Focusing on food is a good place to start. According to a 2012 study, food-related processes release about one-fifth of the UK's total annual greenhouse gas emissions, or 167 million tonnes of CO_2e. (Greenhouse gas emissions are often measured in CO_2e – carbon dioxide equivalent – for simplicity. This is a single measure that includes the warming potential from all greenhouse gases emitted by a given industry, including carbon dioxide, methane, nitrous oxides and so on.)

NO MEAN FEAT

There's another reason why Brits wanting to lower their carbon footprint should begin with their diet: it's one aspect of our lives over which we have a relatively high degree of control. "Many people are in rental accommodation so there's little they can do to make their home more energy efficient, and they don't necessarily have much choice about transportation to and from work," says Prof Peter Scarborough at the University of Oxford, who researches population, nutrition and sustainability. "But diet is absolutely something they can choose to change."

This doesn't necessarily mean that footprint labelling on food will help UK consumers lower the carbon cost of their diet. For ►

LEFT UK-grown tomatoes need to be grown in heated greenhouses. This gives them a bigger carbon footprint than Spanish tomatoes that are transported to the UK

> **"EVEN WHEN YOU ACCOUNT FOR TRANSPORTATION, THE SPANISH TOMATO HAS A LOWER CARBON FOOTPRINT THAN THE BRITISH TOMATO"**

several years now, nutritional 'traffic light labels' have been added to some foods. Scarborough has conducted research into the way UK consumers respond to such traffic light labelling, but has found that it is difficult for people to use the information to make decisions.

If, for instance, one product has two 'green lights' and two 'red lights', a consumer might legitimately wonder whether it is healthier than a rival product with one 'green', one 'red' and two 'ambers'. Likewise, a consumer standing in the food aisle might find it difficult to quickly work out whether the carbon footprint of a pre-prepared Bolognese sauce is higher or lower than the carbon footprints associated with a tray of minced beef, an onion, some fresh basil and a bag of fresh tomatoes.

Speaking of tomatoes, they highlight another problem with carbon footprint labels: apparently identical food items can differ drastically in their carbon costs. Last year, Prof Adisa Azapagic and her colleagues at the University of Manchester published a study on the environmental impact of vegetable consumption in the UK, including the carbon footprints that different vegetables carry. Azapagic's team concluded that putting one kilo of UK-grown fresh tomatoes on the British dining table produces 12.5kg CO_2e. Perhaps surprisingly, putting one kilo of foreign-grown tomatoes on the table produces just 1.3kg CO_2e. The explanation for this, says Azapagic, is that the climate in the UK means tomatoes must be grown in greenhouses that are heated mainly with electricity. Spanish tomatoes don't carry this carbon cost because tomato plants thrive in warm Mediterranean fields.

This neatly punctures another popular misconception: that imported products must have a higher carbon cost than local food because of transportation. A lot of food is transported by boats and lorries rather than planes, and in environmental terms the cost of transportation is usually tiny compared with the cost of actually growing the food. "Even when you account for transportation, the Spanish tomato still has a much lower carbon footprint than the British," says Azapagic.

VEGETATIVE STATE

So, if eating local won't make a difference, what will? The answer, says Scarborough, is to eat less meat. In 2014, he and his colleagues calculated the carbon footprints of various British diets. A meat-eater diet released between 4.7 and 7.2kg CO_2e each day depending on how much meat it contained – the vegan diet released just 2.9kg CO_2e. Vegetarians and people who eat fish but not meat came out in-between: their daily diets released 3.8kg and 3.9kg CO_2e respectively.

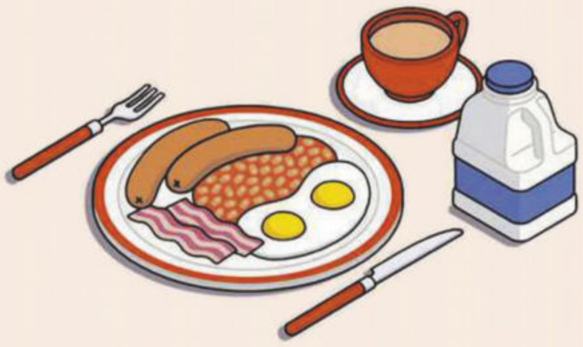
One reason meat has such a high carbon footprint is that livestock is typically fed grain that could instead be given directly to humans. Animals then use the energy in that grain for all manner of processes including maintaining body temperature and keeping their internal systems functioning. A relatively small

GETTY IMAGES ILLUSTRATION: PAUL BUTT

THE CARBON COST OF FOOD

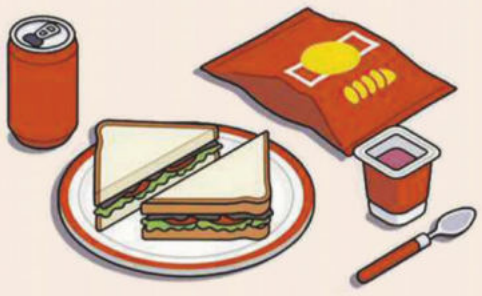
It is surprisingly difficult to work out the carbon footprint associated with our diets: it depends as much on where and how the food we buy was grown as what we actually eat. For instance, some beef comes from calves raised within dairy herds, while other beef comes from calves raised in non-dairy herds. Researchers argue the 'dairy beef' carries a significantly lower carbon footprint because the herd is effectively growing two products – milk and beef – lowering the carbon footprint of both. The following is a very rough guide of the carbon cost of food, using the same data that Dr Graham Horgan at Biomathematics and Statistics Scotland and his colleagues are using in their algorithm.

HIGH FOOTPRINT



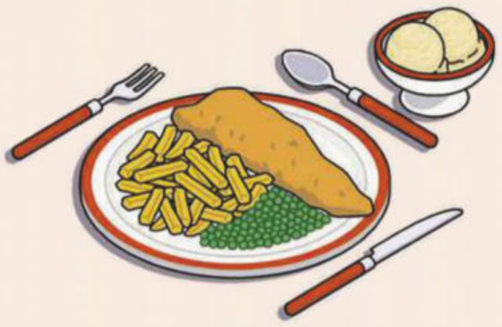
BREAKFAST

Two rashers of bacon (0.6kg CO_2e)
Two small sausages (0.4kg CO_2e)
Two eggs (0.2kg CO_2e)
Portion of baked beans (0.1kg CO_2e)
Cup of tea with full-fat dairy milk (0.05kg CO_2e)



LUNCH

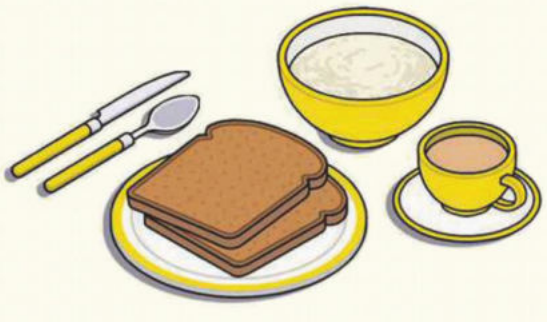
Roast beef sandwich with tomato, lettuce and mayonnaise (1.78kg CO_2e)
Packet of crisps (0.1kg CO_2e)
Pot of yoghurt (0.2kg CO_2e)
Can of fizzy drink (0.1kg CO_2e)



DINNER

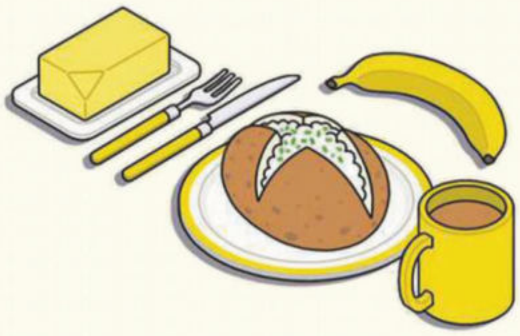
Portion of cod (0.9kg CO_2e)
Portion of chips (0.1kg CO_2e)
Portion of peas (0.02kg CO_2e)
Two scoops of ice cream (0.4kg CO_2e)
TOTAL: 4.95kg CO_2e
*Over the course of a year, this is the same as a petrol car travelling roughly 14,200km***
(London to Perth, Australia is 14,470km)

MEDIUM FOOTPRINT



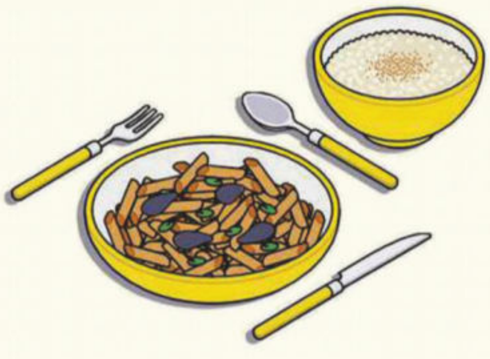
BREAKFAST

Porridge with full-fat dairy milk (0.24kg CO_2e)
Two slices of wholegrain toast with butter (0.27kg CO_2e)
Cup of tea with full-fat dairy milk (0.05kg CO_2e)



LUNCH

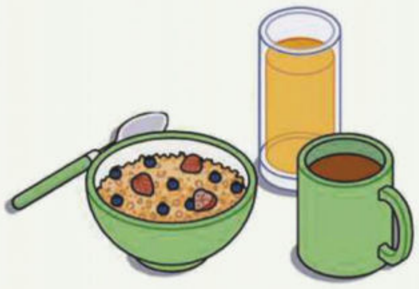
Baked potato with butter and cheese (0.73kg CO_2e)
Banana (0.21kg CO_2e)
Cup of coffee with full-fat dairy milk (0.09kg CO_2e)



DINNER

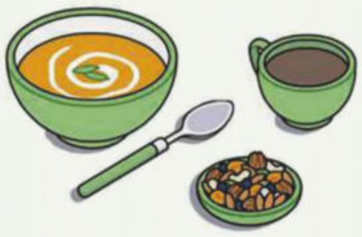
Seafood pasta in a tomato sauce* (1.31kg CO_2e)
Rice pudding (0.3kg CO_2e)
TOTAL: 3.2kg CO_2e
*Over the course of a year, this is the same as a petrol car travelling roughly 9,197km***
(London to Quito, Ecuador is 9,214km)

LOW FOOTPRINT



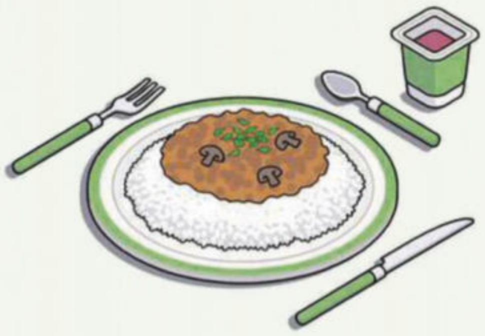
BREAKFAST

Bowl of muesli with soya milk (0.13kg CO_2e)
Glass of orange juice (0.4kg CO_2e)
Cup of black tea (0.01kg CO_2e)



LUNCH

Butternut squash and carrot soup* (0.18kg CO_2e)
Nuts and dried fruit (0.25kg CO_2e)
Cup of black coffee (0.05kg CO_2e)



DINNER

Portion of rice (0.36kg CO_2e)
Portion of lentil and mushroom curry* (0.14kg CO_2e)
Pot of yoghurt (0.2kg CO_2e)
TOTAL: 1.72kg CO_2e
*Over the course of a year, this is the same as a petrol car travelling roughly 4,943km***
(London to Montreal, Canada is 5,200km)

*Not including carbon footprint associated with minor ingredients including herbs and spices
**Assuming the average 5-seater petrol car emits about 127g of CO_2 per kilometre.

ABOVE Insects are a healthy source of protein with a much lower carbon footprint than meat

fraction goes into building the muscle and other tissue we consume as meat, making the process of 'growing' meat extremely inefficient – although Scarborough says the problem isn't as bad for small animals like chickens. "You don't have to feed a chicken anywhere near as much [as you must feed a cow] to get a kilogram of meat," he says.

Even so, all meat carries a relatively high carbon cost. Perhaps in recognition of this fact there has been an upsurge in the number of vegans in the UK. According to some estimates, there are 600,000 British vegans today – four times as many as in 2014. But vegans in the UK are still outnumbered roughly 100 to 1 by non-vegans. Even if people are convinced of the environmental benefits of going vegan, they may be reluctant to make that shift. They might even balk at the idea of replacing lamb or beef with low-carbon alternatives: swapping a beef burger for a locust burger, for instance, or trying what might be the next food trend: lab-grown meat.

> "THE PROBLEM IS THAT THE NUMBER OF ANIMALS IN THE FOOD SYSTEM RIGHT NOW IS OVERWHELMING IT"

Prof Ermias Kebreab, a biologist and ecologist at the University of California, Davis, thinks that there might be a way to sidestep this reluctance. If we are unwilling to change our own diets, then perhaps the solution is to change the diets of the animals many of us eat instead.

Last year, he and his team demonstrated that by supplementing animal feed with about 1 per cent by weight of a particular strain of seaweed, they could half the amount of methane that cows belch into the atmosphere – known as 'enteric methane'. This is because the seaweed reduces the ability of microbes in the cow's stomach to generate the methane: the animals burp out larger quantities of hydrogen gas instead, which has an indirect, smaller impact on global warming. "Most of the emissions [associated with cattle] are from enteric methane," Kebreab says. "So, if you are able to reduce the emissions by 50 per cent – that's absolutely huge."

Encouraging though this is, it doesn't reduce the carbon footprint of beef and lamb to the level of beans or pulses, says Scarborough. Supplementing livestock diet with seaweed can't change the fact that most of that animal feed consists of grain we could eat ourselves. Some consumers might protest that the beef on their plate comes from 'pasture-raised' cows that ate grass rather than grain – but Scarborough says many of these animals are actually brought into cow sheds at night and given grain.

HAVE YOUR STEAK AND EAT IT TOO

At this point, one might be forgiven for concluding that

LEG OF LAMB
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Per ½ Pack
Energy 316kJ 76kcal 4%
Fat 2.7g 4%
Saturates 0.6g 3%
Sugars 0.4g <1%
Salt 0.9g 15%
of an adult's reference intake (8400kJ/2000kcal)
Per 100g
Energy 451kJ 108kcal
MPS1583/0
P02770

LEFT Meat consumption is falling; there are four times as many vegans in the UK today, as there were six years ago

BELOW Quorn Foods has been working with researchers to calculate the carbon cost of its meatless products

Scarborough and researchers like him will only be satisfied when all of us have adopted a vegan diet. He stresses that this is far from being true. In fact, he says, some scientific models suggest it is slightly more efficient to have small numbers of livestock in the agricultural system than none. For instance, in manageable quantities, animal manure is a useful fertiliser. "The problem is that the number of animals in the food system right now is overwhelming it," he says.

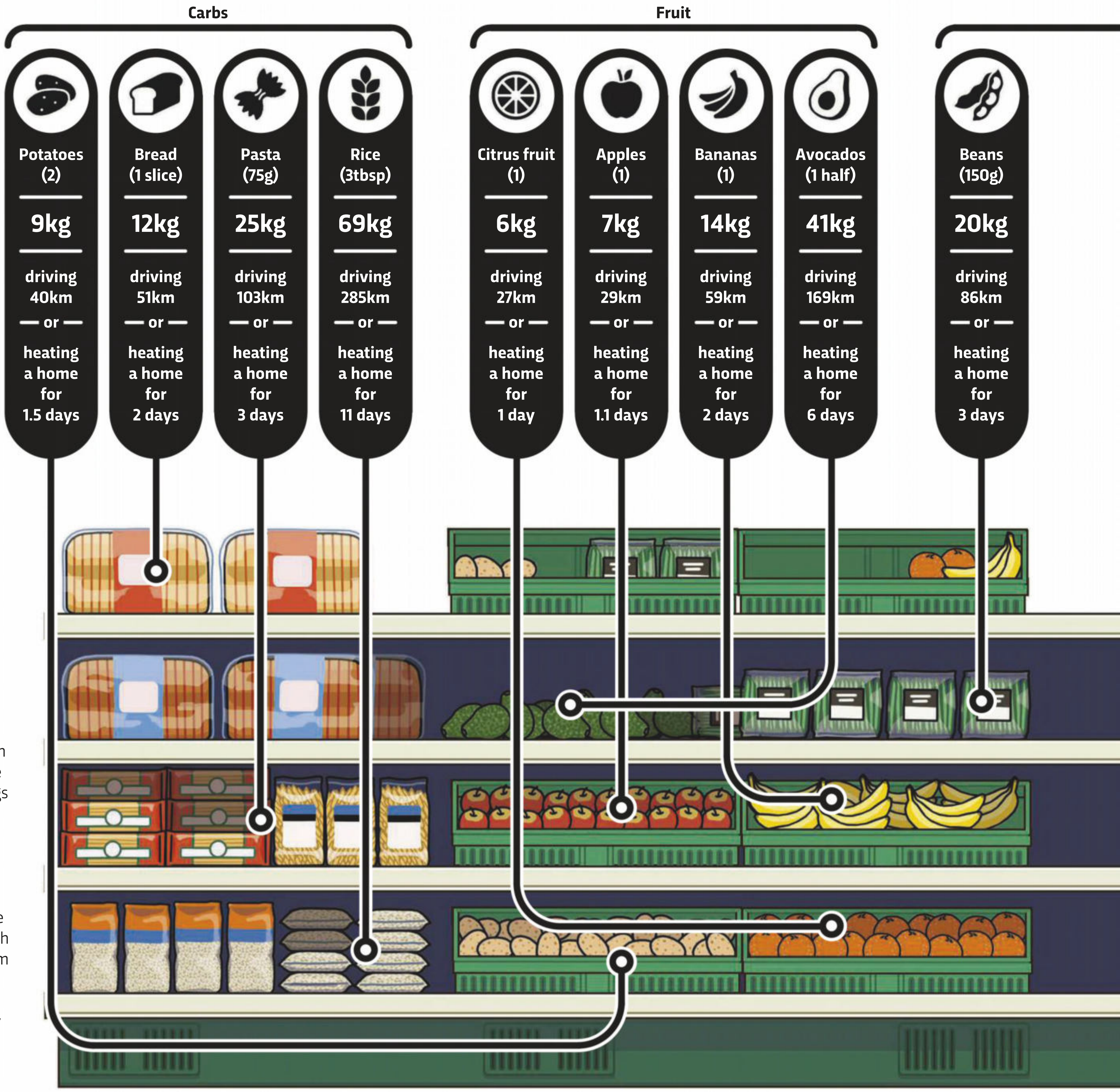
It's not about giving up meat, says Scarborough, but eating far less of it. Doing so is good for animal welfare too. If we eat less meat, we can 'afford' – from an environmental perspective – to allow farm animals to live a free-range life rather than raise them through intensive farming. In other words, British consumers should be able to adopt a diet with good environmental and ethical credentials – if they are willing to eat no more than about one portion of meat per week.

Dr Graham Horgan and his colleagues at Biomathematics and Statistics Scotland designed an algorithm (**muncher.aws.bioss.ac.uk**) that aims to nudge people towards making those kinds of dietary changes. It assesses someone's food shopping list and, using data on the range of carbon footprints associated with each product, suggests relatively small tweaks that should reduce the carbon cost while still meeting nutritional requirements. For instance, the first thing the algorithm does is increase or reduce the quantity of any given item on the list by up to 50 per cent. Then it considers adding small quantities of foods not on the shopping list – a tin of mackerel, for instance – that can provide key nutritional requirements at a relatively low carbon cost. "Our approach was to try to avoid saying 'cut out red meat altogether' and simply say 'eat less red meat'," says Horgan. "I feel that might be more acceptable to consumers."

Just by making these changes, about 50 per cent of people in a 2016 study published by Horgan and his colleagues could continue to eat meat but also reduce the carbon footprint of their diet to a level where it released only 3.1kg CO_2e per day. This isn't too much higher than the 2.9kg CO_2e per day for a *vegan* diet that Scarborough calculated. Horgan now wants to test whether the algorithm can have a real-world impact on the dietary choices made by average British consumers.

Beyond cutting down on meat there is at least one more thing consumers can do to lower their dietary carbon footprint: learn ➲

PETER BOLTER, GETTY IMAGES X2



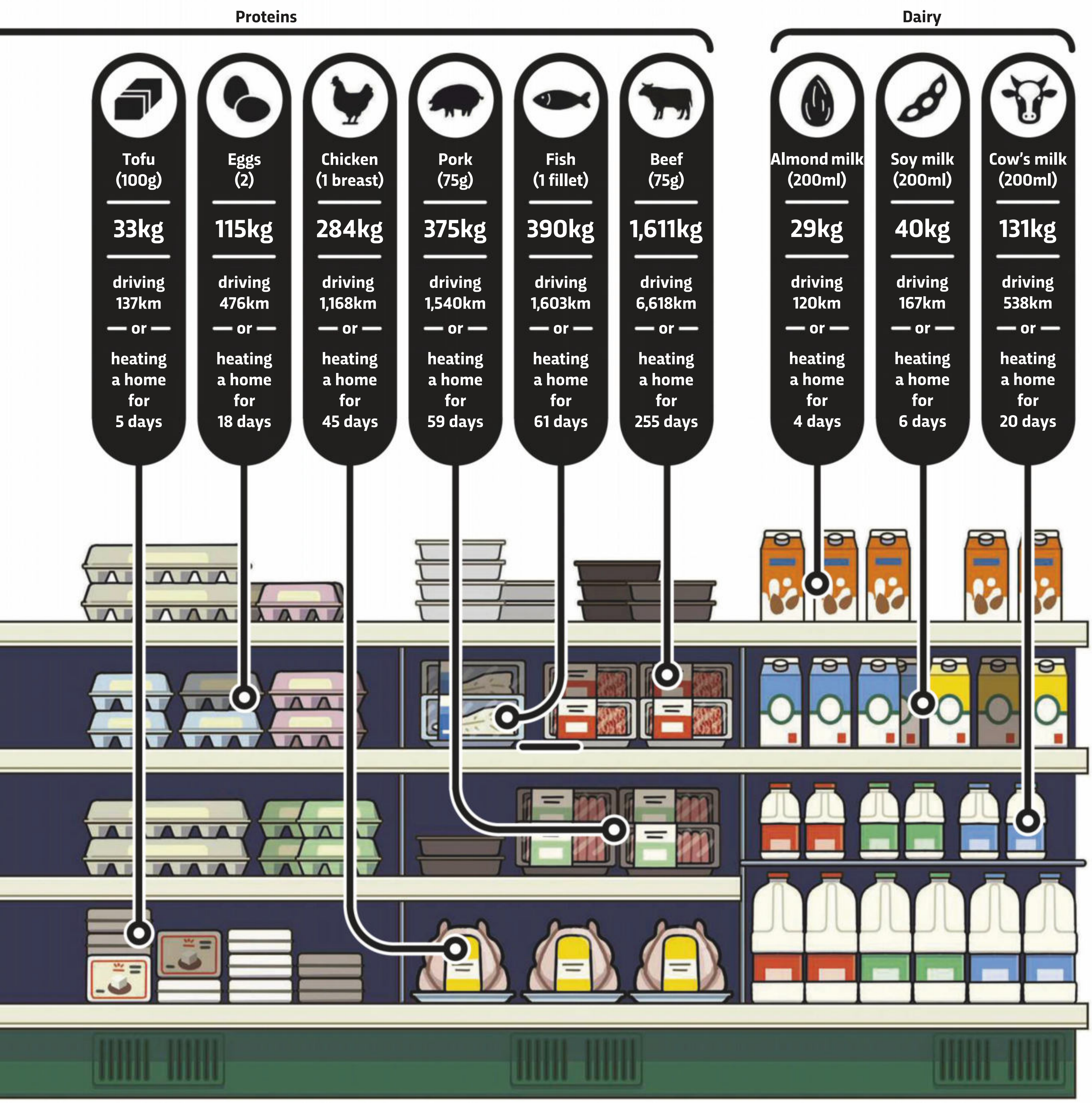
In each case we've calculated the consumption over an entire year, and have assumed 3-5 servings a week.

CREDIT: The data in this infographic was calculated using the BBC's climate change food calculator, which is based on data from researchers at the University of Oxford and the Agroecology and Environment Research Division in Zurich, Switzerland.

> "PEOPLE ASSUME FOOD HABITS ARE STUCK FOR LIFE, THAT PEOPLE DON'T CHANGE – BUT IT'S ABSOLUTELY NOT TRUE"

➤ to appreciate the value of food. Some estimates suggest that the food we buy but then throw away adds up to 214 calories per person each day. But an analysis published earlier this year concluded that the problem is worse than that. Dr Monika van den Bos Verma and her colleagues at Wageningen University & Research in the Netherlands found that each of us, on average, actually wastes 527 calories each day. Alarming as this conclusion is, she points out that it also represents a golden opportunity. "Yes, it's a bigger problem than we thought," she says. "But that means if we can solve it, it's a bigger solution as well. That's a big 'if', but I think we can do it."

Right now, there isn't much stigma associated with throwing away bread that has gone stale, or bananas that have overripened. But what we deem socially acceptable can change relatively rapidly, as we've seen in recent decades with public perceptions



of smoking. With more awareness about the time and energy that goes into producing food, we might be more willing to turn stale bread into breadcrumbs, or overripe bananas into banana muffins. Or we might simply become better at purchasing just the food we need, rather than bulk-buying products and throwing food away.

Scarborough agrees that attitudinal shifts to food are possible. "People assume food habits are stuck for life, that people don't change – but it's absolutely not true," he explains. "If you look at the food we consume now versus 60 years ago it's very different."

Consumers should be able to adopt lower-meat diets and waste less food, not least because this is what most British people have done for centuries. So if we can make those changes, will it bring the zero-carbon diet into view? In one sense, the answer is a firm no: we will always need to use energy to produce even the most frugal of diets. But eventually it may be possible to offset most – or even all – of the emissions associated with our food, particularly if more of us reduce our meat consumption. This is partly because with less demand for pasture it will be possible to 'rewild' agricultural land, and an acre of forest can absorb far more carbon than an acre of pasture. No one has run the numbers, but it's an intriguing idea, says Scarborough. "The question of whether the food system as a whole can be zero-carbon over the long run? That's an interesting one." **SF**

by COLIN BARRAS
Colin is a freelance science writer and editor, based near Ann Arbor, Michigan.

ILLUSTRATION: PAUL BUTT

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HOW TO STAY YOUNG

Could fasting help you turn back the hands of time?

Back in 2012 I made a science documentary called *Eat, Fast And Live Longer* which explored the science behind approaches to extending healthy life and holding back the hands of time. I concluded that the only proven way to do this was by calorie restricting. Now, eight years later, there's stronger proof of the benefits from calorie restriction or intermittent fasting (where you reduce your calories for two days a week).

The first evidence came from researchers at Cornell University in the 1930s. A team led by Dr Clive McCay decided to put a group of mice on a low-calorie diet. They were amazed to discover that mice who were fed 30 per cent fewer calories than normal, lived 40 per cent longer. The longer-lived mice were also less prone to normal age-related illnesses, such as cancer and heart disease.

Subsequent studies have shown the same is true for almost every other animal species that has been put on a calorie-restricted diet – they not only live longer but are far more healthy.

So what about humans? In a recent study, CALERIE (Comprehensive Assessment of the Long-Term Effects of Reducing Intake of Energy), researchers tested the effects of long-term calorie restriction on non-obese people. In the study, 218 healthy people of a normal weight were randomly assigned to either cutting daily calorie intake by 15 per cent for two years, or continuing as normal.

> **“Even people who are already healthy and lean may benefit from a calorie restriction regimen”**

Those in the calorie restriction group, not surprisingly, lost weight (an average of nine kilograms) but also saw big improvements in a range of risk factors, including cholesterol, blood pressure and C-reactive protein (a measure of inflammation). They also reported improvements in sleep, mood, sex drive and quality of life.

As one of the lead researchers, Leanne Redman, associate professor of Clinical Sciences at Pennington Biomedical Research, puts it, “We found that even people who are already healthy and lean may benefit from a calorie restriction regimen.”

How does it work? Well, another recent finding is that calorie restriction suppresses the normal age-related increase in inflammation, something widely recognised as a major driver of dementia, heart disease and cancer.

Personally, I find the idea of long-term calorie restriction a bit too challenging, which is why I decided to put myself on the 5:2 diet, a now popular form of intermittent fasting. It dramatically improved my health and I was delighted to read a recent paper in the *New England Journal Of Medicine* which looked at all the available research and concluded that the benefits of intermittent fasting are widespread. The paper said that intermittent fasting not only improves blood sugar regulation and blood pressure, but increases resistance to stress and suppresses inflammation.

All good reasons to cut back a little. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. You can watch clips at **bit.ly/trust_me_clips**

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

GOING VIRAL

What can online game *World Of Warcraft* teach us about COVID-19?

It was late in the afternoon when Eric and his buddies set out on an adventure to a new part of town. It was sunny and the birds were singing, as they always did. And it was here, in this tranquil little corner of the adventurers' brave new world that they caught the bug that would take down a civilisation.

Eric first realised something was up when his buddy Zelden started spewing blood from his eyes. "Holy crap!" he thought to himself, before tapping out a healing spell on his keyboard, and throwing it across the screen. It landed on target and the bleeding subsided, but Zelden had taken damage. And so had the gang. Anyone within Zelden's bleeding distance was touched by Corrupted Blood, the pandemic that destroyed all life in the towns of the online game *World Of Warcraft*. The disease was meant to only last for a short time and be restricted to a certain region of the game. But due to an oversight, the programmers didn't realise that non-player characters and pets were capable of spreading the infection. It become a pandemic, affecting a number of the *World Of Warcraft* servers.

It was 2005, and virtual worlds researchers like me were transfixed by what human behaviour we might observe in these digital social Petri dishes. There had been conferences about player-created governments and justice systems, economics and social contagions. But until Corrupted Blood was accidentally let loose, we hadn't witnessed something like this unfold in the wild. And epidemiologist Eric Lofgren got caught right in the middle of it.

> "The programmers didn't realise that non-player characters and pets could spread the infection"

The result of his serendipitous fieldwork was several papers published in highly respected infectious disease and epidemiology journals. He and his colleagues described the things that people did which they had been unable to predict. There were the healers who chose to put their (virtual) lives at risk on the frontline of the (virtually) deadly pandemic; the rumour mills that shut down the economic and transport systems; the people who broke quarantine; characters who hid in the wilderness. "Travel bans don't work," Eric told me recently. People have to go to work. They want to see family. They don't believe health officials. And some people like to be agents of chaos, spreading the disease "for the lolz" – or for ransom.

This isn't just information he's picked up from observing a virtual pandemic; these are things learnt from the evoluion of real-world pandemics. And yet, the virtual world provided an interesting place to watch human behaviour that reflects what may happen with something like COVID-19. However, he is the first to point out the differences – mostly it comes down to "it's a game".

Yet that's not what digital designers believe. There's a lot of thinking in Silicon Valley about how our online and offline Venn diagrams overlap. Technology, they believe, can be a window into our subconscious. But we cannot create facsimiles of the complexity of natural human social systems. Corrupted Blood was an unpredictable incident due to human error. What might bring down civilisation isn't a bug in the system; it's the belief we can fix the system and the humans within it. **SF**

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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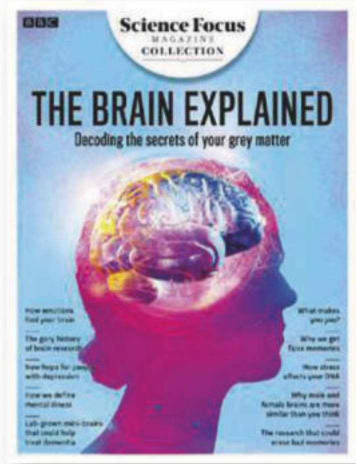
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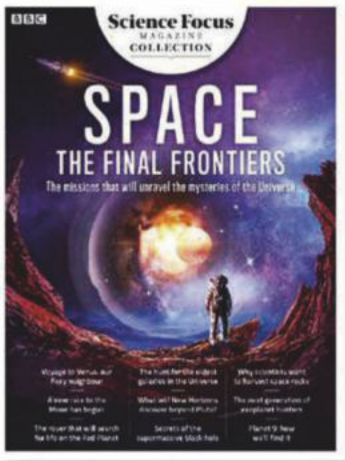
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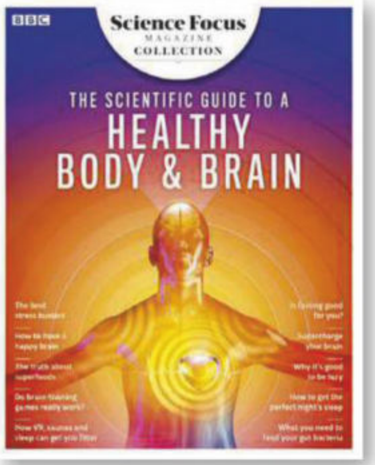
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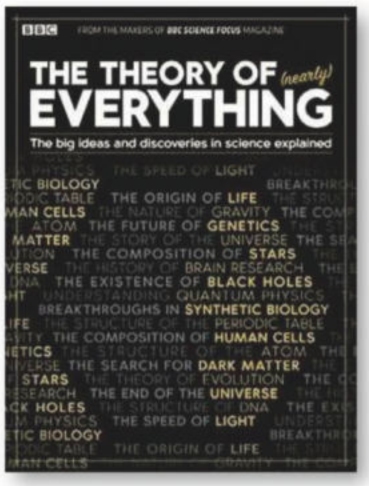
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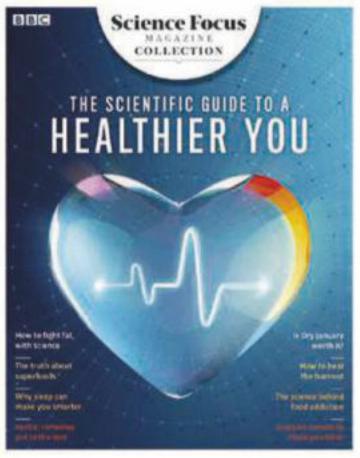
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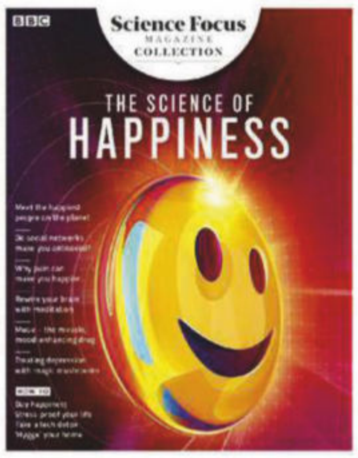
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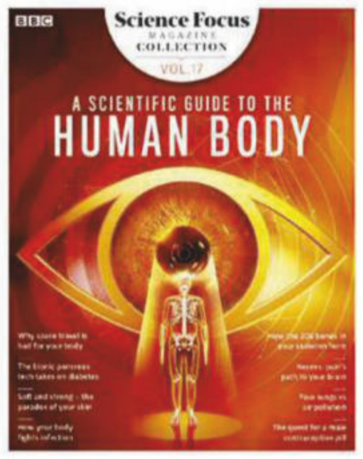
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GETTY IMAGES

FAMILY TREE FORENSICS

In the US, hundreds of long-forgotten cold cases are being reopened by detectives who mine new DNA databases for leads, but it seems time might be running out…

by SIMON CROMPTON

When she answers my call, Paula Armentrout is buzzing with the news that's just come through. Her company's DNA analysis and genetic genealogy service has just led to the arrest of a man for two murders that happened four years ago. It's the 101st case of serious crime solved as result of genetic detective work by Parabon NanoLabs. The service was launched just two years ago, in May 2018.

The Cincinnati man who's been arrested beat a mother and son to death in their home in 2016. He might have thought he'd got away with it, as at the time of the initial investigation, the DNA sample found at the crime scene matched nothing on the police databases. The case went cold.

But Virginia-based Parabon provided a new analysis of the DNA sample, which allowed it to be compared with hundreds of thousands of other DNA samples – not on police databases but on online genealogy services by members of the public wanting to find relatives through genetic similarities. Just as in 100 other cases, the analysis revealed people related to the suspect, some distantly. Parabon's genetic genealogists then reverse-engineered a family tree, joining the dots between the crime scene DNA and relatives using official birth, death and marriage records and obituaries, to produce a list of leads and potential suspects for whom the time, the place and the DNA fitted.

COLD CASES

In case 101, the process led to 51-year-old Jonathan Hurst. Mobile phone records confirmed that Hurst was in the area of the crime scene on the day of the murders. Police then tested his DNA and confirmed a match to the crime scene DNA.

"In this case, we've been assisting law enforcement agencies as needed for around a year and a half," says Armentrout, Parabon's vice president. "There are a lot of our cases in that stage, with agencies investigating leads we've generated or following up recommendations that we've given them from our genealogical perspective."

Genetic genealogy has suddenly become big in United States law enforcement. The explosion began in April 2018, when California law authorities announced the identification and arrest of the suspected Golden State Killer, responsible for 12 killings, 51 rapes, and more than 120 burglaries in California between 1974 and 1986. Police had drafted in the help of genetic genealogists, who pointed to former police officer Joseph James DeAngelo after they had uploaded their new analysis of his DNA data to an ➲

> "GENETIC GENEALOGISTS THEN REVERSE-ENGINEERED A FAMILY TREE, JOINING THE DOTS BETWEEN THE CRIME SCENE DNA AND RELATIVES"

ABOVE CeCe Moore (second from left) and the Parabon team

▶ open-source genealogy service called GEDmatch and compared it with the DNA records of hundreds of thousands of people who wanted to research their family tree.

Just one month after the Golden State Killer announcement, DNA engineering company Parabon launched its genetic genealogy service – also using GEDmatch – and unsolved violent crime cases came flooding in from police departments.

Parabon analyses DNA in a more detailed way than law enforcement DNA databases. It examines hundreds of thousands of DNA loci via a technique called 'single nucleotide polymorphism analysis' (SNP) rather than the 13 to 17 loci of traditional police 'short tandem repeat' (STR) techniques (see box, right). DNA ancestry websites like GED also analyse DNA using SNP.

To date, Parabon has worked on 450 cases, with the average case being 25 years old. The company also takes on current cases where there's an urgent need for leads. In 2018 they took on the case of a man who had raped a 79-year-old woman in Utah. Parabon's chief genetic genealogist CeCe Moore knew that narrowing down suspects using family trees might be the only means of preventing further crimes.

"They desperately wanted to solve this case before he attacked another woman or he came back to the victim's home again. She was petrified, couldn't sleep at night, afraid he would come back and finish the job. So that was a very high pressure case." The perpetrator was arrested in July 2018, just three months after the crime.

Now competition for genetic genealogy business is growing. In February last year, Bode Technology joined Parabon in offering the service to law enforcement, followed by Verogen Inc in December (when it also acquired GEDmatch). But Parabon claims no one offers a complete service like theirs, combining genealogy with a 'snapshot' genetic phenotyping service. This genetic phenotyping creates CGI images of suspects' faces from analysis of key loci in their DNA. Parabon has sold this service to police forces in 13 countries.

But the rush to find new ways of catching criminals through detailed SNP DNA analysis is controversial. Rumblings started as soon as details of the Golden State Killer capture emerged. Was it right that people who submitted their personal information for the purpose of finding relatives should have their families investigated for crimes? Some people involved in subsequent cases have complained about feeling misled that their DNA has been used to build cases against relatives.

Crime, science and ethics academics have also voiced their worries. Writing in the journal *Genetics In Medicine*, Dr Caitlin

"DNA PHENOTYPING HIGHLIGHTS HOW MUCH INFORMATION IS CONTAINED IN OUR GENETIC DATA. THIS INCLUDES INFO ABOUT OUR PREDISPOSITION TO DISEASE AND MENTAL HEALTH PROBLEMS"

PARABON LABS, GETTY IMAGES X2

HOW TO SOLVE A CRIME WITH GENETIC GENEALOGY

1. Crime enforcement agency (police department, sheriff's office) contracts a DNA investigation company to help them crack a cold case.

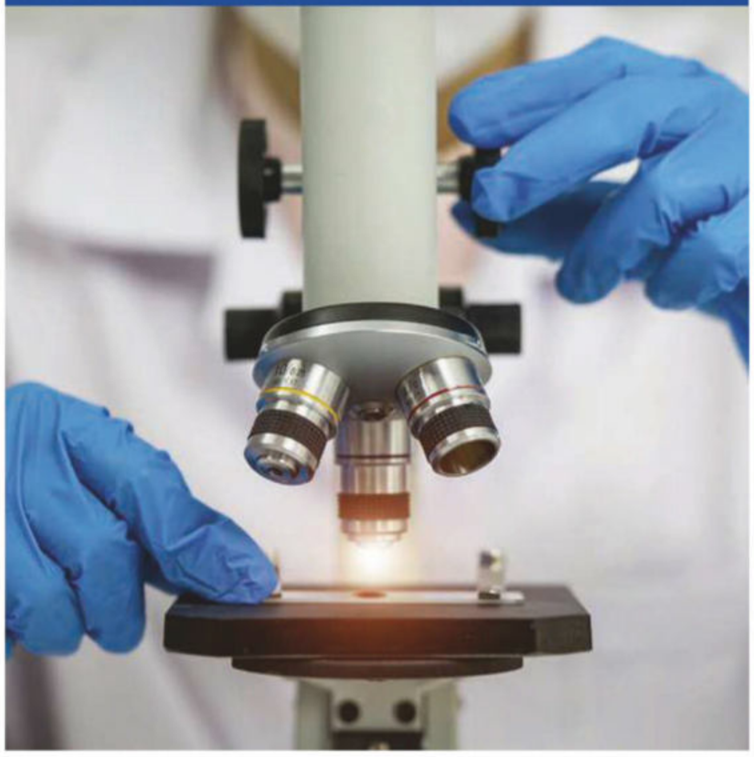
2. The company analyses crime scene DNA and converts it into a file representing its unique sequence of bases (adenine, cytosine, guanine, and thymine).

3. Around 700,000 single nucleotide polymorphisms (SNPs) – the most common points of genetic variation between people's DNA – in the data are examined. An Excel spreadsheet showing the information about these points (loci) would be 26 columns wide and 851,000 rows long.

4. SNP DNA analysis is also used by online genealogy services to find distant relatives, while police DNA databases use a more basic short tandem repeat (STR) analysis, which allows identification of only close relatives.

5. The company uploads the data file to a genealogy service that has agreed to be used for law enforcement, such as GEDmatch. SNPs are compared to hundreds of thousands of other samples. The genealogy service returns a list of people who have DNA matches.

6. Genetic genealogists employed by the company use this information to find common ancestors, build family trees and deduce living descendants who might fit the time and place of the crime and other evidence.



ABOVE In 2018, information obtained from genetic genealogy sites allowed police to finally track down the suspected Golden State Killer, former police officer Joseph James DeAngelo (pictured). He'd carried out a series of rapes and murders in the 1970s and 1980s, but had managed to avoid capture

Curtis, genomic research fellow at the University of Queensland, said that the growth of both forensic genetic genealogy and DNA phenotyping highlights the need for greater protection of genetic data. "Police genealogy shows how one person's decision about their genetic data can impact not only close relatives, but distant ones," says Curtis. "DNA phenotyping highlights how much sensitive information is contained in our genetic data." This includes information about our predisposition to disease and mental health problems, as well as what we look like.

PRIVACY CONCERNS

Some of the concern has dampened down as genealogy websites have made it clearer whether or not they are used in law enforcement programmes, and now make it necessary for users to 'opt in' if their DNA is to be used forensically. Parabon says it only uploads samples to GEDmatch and now another company called FamilyTreeDNA. Other ancestry search companies, such as Ancestry.com and 23andme, do not allow access for crime-solving.

Moore, who was a well-known ancestry detective in the US before she developed forensic genetic genealogy techniques with Parabon, also had early concerns about using DNA designated for family history work for crime-solving.

Now her concern is that new privacy requirements are shrinking the DNA pool that crime samples can be compared against. Last year, GEDmatch opted its entire database out of law enforcement matching, and required each person using the service to actively opt in. The result is that Parabon now has just 200,000 people ▶

HOW ‘SNAPSHOT’ DNA PHENOTYPING WORKS

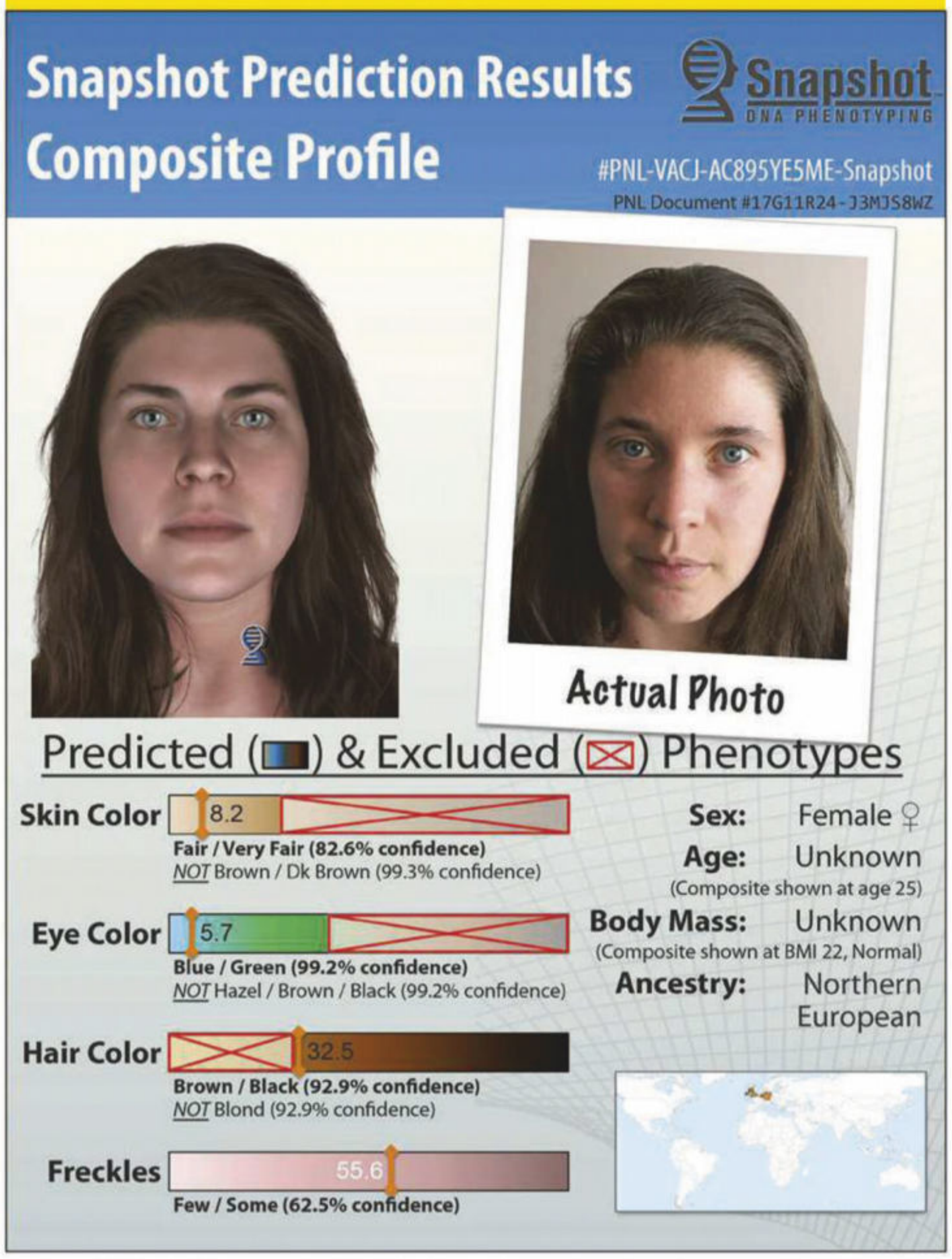
- Parabon uses its analysis of crime scene DNA to predict the physical appearance and geographic ancestry of a person of interest.

- SNP analysis of DNA sample reveals genetic variants that can predict: genetic ancestry, eye colour, hair colour, skin colour, freckling and face shape.

- Each trait is given a confidence rating: how likely it is, given the strength of genetic markers.

- This data is built into computer-generated images of the crime suspect’s face. A small study from the University of Texas found these visual predictions of facial features and ancestry to be generally recognisable. But Denise Syndercombe Court, professor of forensic genetics at King’s College London, questions whether the representations are robust enough.

- Genetic phenotyping is often used alongside genetic genealogy, to narrow down potential suspects identified in family trees. For example, if a person of interest is known to be African American, but DNA phenotyping suggests they are likely to have green eyes, genealogists will focus on the branch of the family tree that has most European influence.



Snapshot Prediction Results
Composite Profile

Snapshot DNA PHENOTYPING

#PNL-VACJ-AC895YE5ME-Snapshot
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Actual Photo

Predicted (▬) & Excluded (☒) Phenotypes

Skin Color 8.2
Fair / Very Fair (82.6% confidence)
NOT Brown / Dk Brown (99.3% confidence)

Eye Color 5.7
Blue / Green (99.2% confidence)
NOT Hazel / Brown / Black (99.2% confidence)

Hair Color 32.5
Brown / Black (92.9% confidence)
NOT Blond (92.9% confidence)

Freckles 55.6
Few / Some (62.5% confidence)

Sex: Female ♀
Age: Unknown
(Composite shown at age 25)
Body Mass: Unknown
(Composite shown at BMI 22, Normal)
Ancestry: Northern European

* IMAGE SHOWS A VOLUNTEER, NOT A CRIMINAL

> “THE UK NATIONAL CRIMINAL INTELLIGENCE DNA DATABASE, 25 YEARS OLD THIS YEAR, HOLDS INFORMATION ON AROUND 10 PER CENT OF THE UK POPULATION AT ANY ONE TIME”

► to compare against on GEDmatch, compared with 1,000,000 in 2018. “It’s now much more difficult to solve these cases and narrow them down as specifically as we used to,” she says. “We don’t have enough data, which means a lot more work has to go into it.” Investigators may need to ask certain lines of descendants for DNA samples.

There are other limitations that may restrict expansion. Those who submit DNA to research their ancestry tend to be of European extraction – standing in the way of growth in many countries. Data protection laws in Europe are generally tighter than the United States. And some experts believe there is simply no need for genetic genealogy in countries that operate an effective crime database.

Denise Syndercombe Court, professor of forensic genetics at King’s College London, says that the UK hasn’t gone down the genetic genealogy route, partly because it already has a database that represents a more relevant population. The UK National Criminal Intelligence DNA Database, 25 years old this year, holds information on around 10 per cent of the UK population at any one time – because it includes DNA data on crime suspects as well as those who have committed crimes.

According to Syndercombe Court, a complicated DNA analysis that can identify distant cousins isn’t required if your crime database is comprehensive enough. “The UK database contains information on one in eight males between the age of 15 and 45 to 50, so it’s very powerful,” she says. In the case of unsolved serious offences, DNA can be compared to this database and it is likely to pick up close relatives – parents, children, full siblings and sometimes half siblings and uncles.

“The problem in the United States is that they haven’t been putting their felons onto an identifiable DNA database. Most of these people could have been picked up many years ago if the United States had a proper governance structure. We have that, so my feeling is that the number of cases it would be useful for in the UK would be very limited.” **SF**

by **SIMON CROMPTON**
(@Simoncrompton2)
Simon is a science, medical and health writer

THE STRANGE CASE OF THE MISSING 7TH DESCENDANT

Eighteen-year-old Angie Dodge from Idaho Falls was raped and murdered on 13 June 1996, and in 1998 Chris Tapp was imprisoned for the crime for 20 years. It wasn't until May 2019 that genetic genealogy provided the leads that not only found the true culprit – Brian Leigh Dripps Sr – but also exonerated Tapp.

CeCe Moore, the chief genetic genealogist of DNA analysis and genetic genealogy company Parabon, remembers it as her most satisfying case. But the path to Dripps was not an easy one. The crime scene DNA was badly degraded, and not obviously suitable for analysis. But enough was decoded for it to come up with several links on GEDmatch and for Moore to begin studying family trees. In total, she worked on the case for 100 hours.

"The person we ended up identifying as the murderer was actually missing from the family tree," she says. "I had narrowed it down to six persons of interest and it was none of those so I was sort of stumped."

Moore realised there must be a seventh missing descendant, who eluded official records and family contact. She suspected this had something to do with a teenage marriage and early divorce between one of the genetically matched men and a young woman. It was likely there had been a child that no one had recorded and no one talked about.

Moore knew she couldn't make enquiries among possible relatives, because that might alert the suspect. So she dug deeper.

The genetically matched man had died, and his obituary didn't mention a son. His wife couldn't be traced. So Moore looked for records of her mother instead. Eventually she found an online obituary, where there was mention of a named grandson.

"The young woman did indeed have a baby son with that first husband, but she left him so early that he clearly was never part of his dad's family's lives," says Moore. "And that was it. Once we found the son, we found he was in Idaho Falls in 1996. He was the seventh missing descendant and it turns out he lived across the street from Dodge at the time she was murdered. We knew the guy had brown eyes – just like the genetic phenotype predicted. And we knew we finally had him after around a year's work."

Brian Leigh Dripps Sr was arrested on 15 May 2019 and confessed to the crimes.

FROM TOP TO BOTTOM Angie Dodge, who was a victim in a case CeCe Moore helped solve; Chris Tapp talks to journalists after his exoneration; Carol Dodge, Angie's mum, is emotional when thanking the people who helped identify the correct suspect; Tapp and Dodge embrace after hearing that Brian Leigh Dripps Snr had been arrested

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ILLUSTRATION: DANIEL BRIGHT

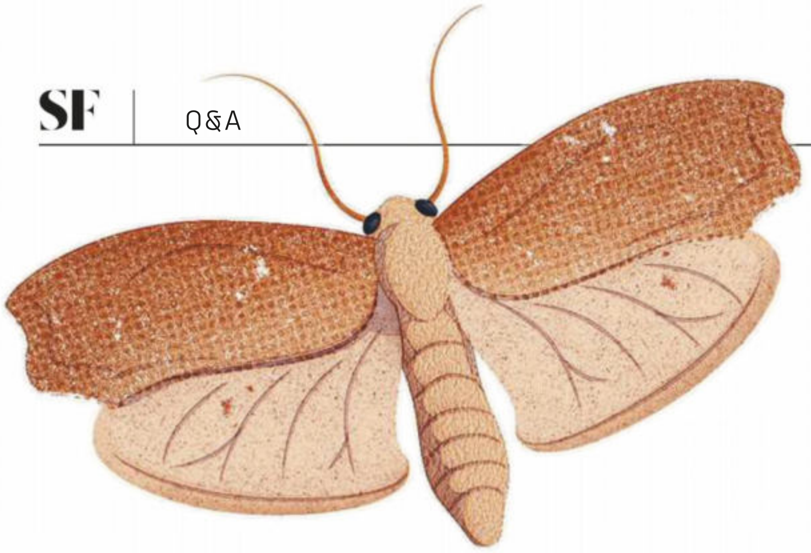
ALEC MADDOCKS, VIA EMAIL

COULD WE BRING BACK AN EXTINCT SPECIES USING DNA, *JURASSIC PARK* STYLE?

To 'de-extinct' an animal, you need a source of the animal's DNA, which provides the blueprint for making it. DNA is sometimes preserved in fossils, and the oldest DNA extracted to date comes from a 700,000-year-old horse bone found in the Canadian permafrost. However, DNA breaks down over time, and scientists think that it's unlikely to be found in any specimen older than a million years. Dinosaurs went extinct 65 million years ago. No dinosaur DNA, no dinosaurs. Sorry!

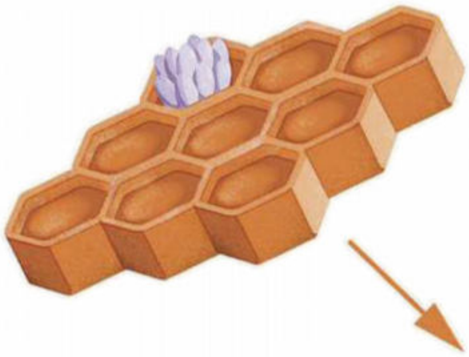
Some other species, however, are fair game. In 2003, scientists briefly de-extincted a type of goat, called the bucardo. DNA-laden cells, taken from the last living female before she died, were used to create a clone, and the resulting embryo was transplanted into the womb of a living domestic goat. The bucardo was delivered by Caesarean section, but died shortly after birth due to lung defects. The bucardo was therefore the first animal to be de-extincted, but also the first animal to go extinct twice!

Other de-extinction projects include attempts to revive an Australian amphibian called the gastric-brooding frog, a North American bird called the passenger pigeon and the one and only woolly mammoth. These use a combination of cloning, gene-editing and stem cell methods, but don't hold your breath waiting for the pitter-patter of tiny feet. De-extinction is still very much in its infancy, so for now, take solace in the fact that dinosaurs never really left us. Birds are their direct descendants, and they're everywhere. ***HP***

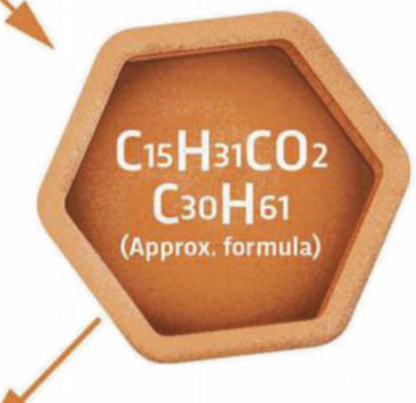


HOW IT WORKS: PLASTIC-EATING CATERPILLARS

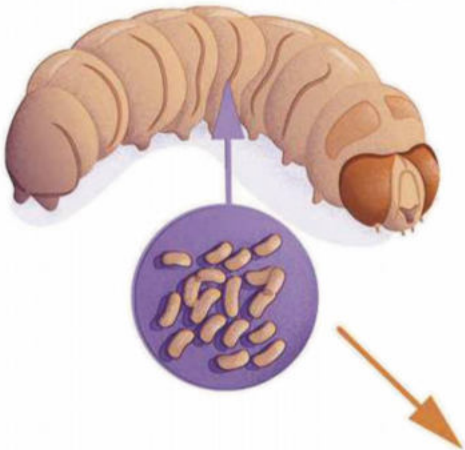
Since the mid-20th Century, plastic production has increased exponentially, and the resulting pollution has become a global environmental issue. Little by little, we are replacing plastics with more environmentally friendly options, but what about the plastic that's already out there? Maybe Mother Nature can help out. Meet the waxworm: traditionally thought of as a pest, its love of beeswax may have a surprising benefit.



Wax moths lay their eggs in beeswax in beehives. When the caterpillars wriggle out, they tunnel through the combs, munching as they go.



Beeswax, the caterpillars' natural diet, and LDPE, a plastic used to make shopping bags, are made from almost identical chains of carbon and hydrocarbon.



The caterpillars' gut bacteria can degrade and process the plastic as a traditional food source, producing biodegradable glycol as a metabolic by-product. These glycol excretions could be reduced by antibiotic treatment, a study has found.

It is hoped that these 'plastivores' may hold the key to better understanding how the biodegradation of plastic works, and may even assist in reducing the volume of plastic in landfills.

PHILIP WELPLY, ST ALBANS

WHAT DOES LUNAR DUST SMELL LIKE?

Apollo astronauts reported that lunar dust found inside their landers smelt like burnt gunpowder. Since there's no chemical similarity between moondust and gunpowder, the smell could have been the dust reacting with oxygen and/or water inside the lander, or due to the release of charged particles from the Sun that had become trapped in the dust. Curiously, though, lunar dust samples brought back to Earth from the Moon are odourless. So whatever caused the smell reported by the Apollo astronauts must have been temporary. ***AGu***

WHY DOES CRYING GIVE ME A HEADACHE?

Crying from fear or sadness (rather than happiness) involves more than just tears. The stress hormones adrenaline and cortisol make the muscles of your face and scalp scrunch up. This increases pressure on your skull, which can cause a tension headache. A long crying session also works your facial muscles, and the lactic acid and other metabolic by-products of muscle fatigue will build up. These chemicals aren't so easily flushed away, because the blood vessels around your face are also constricted by the muscle contractions. The resulting inflammation and nerve irritation turn into a dull aching pain. *LV*

TINA GOODWIN, VIA EMAIL

HOW DO VIRUSES JUMP FROM ANIMALS TO HUMANS?

Every animal species hosts unique viruses that have adapted to infect it. Over time, some of these have jumped to humans – these are known as 'zoonotic' viruses. As our populations grow, we move into wilder areas, which brings us into more frequent contact with animals we don't normally have contact with. Viruses can jump from animals to humans in the same way that they can pass between humans, through close contact with body fluids like mucus, blood, faeces or urine.

As every virus has evolved to target a particular species, it's rare for a virus to be able to jump to another species. When this does happen, it's by chance, and it usually requires a large amount of contact with the virus. Initially, the virus is usually not well-suited to the new host and doesn't spread easily. Over time, however, it can evolve in the new host to produce variants that are better adapted. When viruses jump to a new host, they often cause a more severe disease. This is because viruses and their initial hosts have evolved together, and so the species has had time to build up resistance. A new host species, on the other hand, might not have evolved the ability to tackle the virus. For example, when we come into contact with bats and their viruses, we may develop rabies or Ebola virus disease (EVD), while the bats themselves are less affected. It's likely that bats were the original source of three recently emerged coronaviruses: SARS-CoV (2003); MERS-CoV (2012); and SARS-CoV-2, the cause of the 2019-20 coronavirus outbreak. All of these jumped from bats to humans via an intermediate animal; in the case of SARS-CoV-2, this may have been pangolins, but more research is needed. ***KA***

530

The approximate number of eggs found in the mouth of a parazen fish. It's the first deep-sea fish species that's been found to be a mouth-breeder.

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I DRINK FRUIT JUICE BY THE BUCKETLOAD. IS IT REALLY AS BAD FOR ME AS FIZZY DRINKS?

The amount of sugars in fruit juice can be equivalent to, or even higher than, that found in fizzy drinks. That's bad news – too much sugar puts us at risk of health problems including obesity and type 2 diabetes, as well as tooth decay. With research highlighting these potential health risks, and public awareness increasing, the reputation and popularity of fruit juice have fallen in recent years.

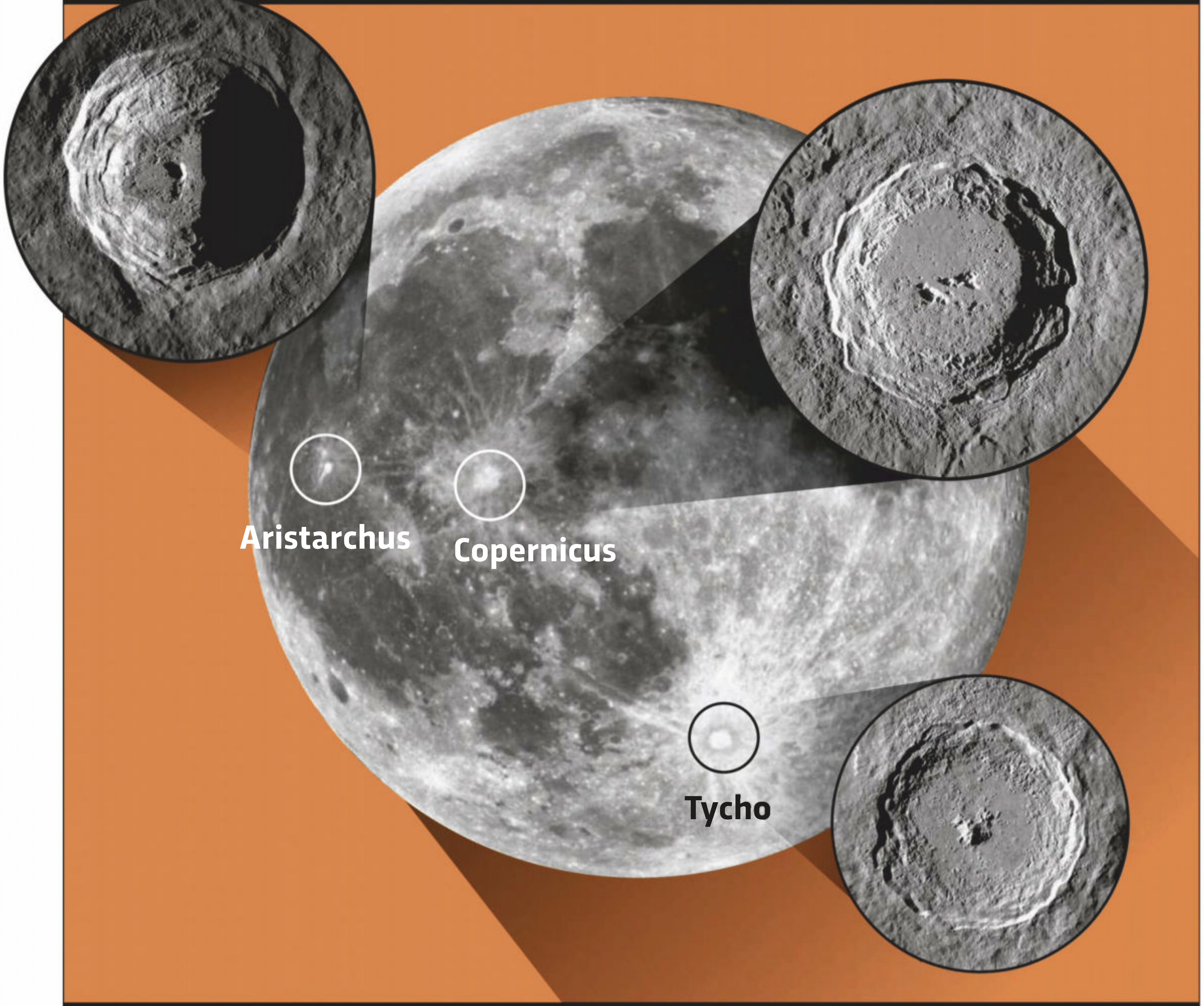
It's not all bad news. Pure fruit juice does contain vitamins, minerals and antioxidants, which are not generally found in fizzy drinks, and these can boost the immune system and help ward off infection and inflammation. So fruit juices are marginally better for you than fizzy drinks. But no matter how much juice you glug down, it'll still only count as one of your recommended five-a-day. This is because when fruit is juiced, sugar is released from the fruit's cells as 'free sugars', and most of the fibre is removed – both of which mean that juice isn't as good for you as the whole fruit.

If you do need a fruit juice hit, the NHS recommends no more than 150ml a day, and drinking with meals to reduce tooth damage. You could also dilute your juices to reduce the proportion of sugar – and this will make them last for longer, too! ***SO***

orange juice

NASA, GETTY IMAGES ILLUSTRATION: DANIEL BRIGHT

ASTRONOMY FOR BEGINNERS



HOW DO I SEE THE SUPERMOON?

WHEN: 8 APRIL AND 7 MAY 2020

This year, April and May are especially good months for moongazers, because we have two supermoons in a row (three if you count the March supermoon).

A full moon 'supermoon' is defined as a full moon that coincides with the Moon being at (or within 90 per cent of) its closest point to the Earth (its 'perigee') as it follows its elliptical orbit around us. A supermoon can be up to 14 per cent bigger and 30 per cent brighter than a normal full moon. Technically, a new moon can also be a supermoon, but we don't tend to mark these because we can't see them! The next full moon supermoon after these will be in April 2021.

Supermoons are a great opportunity to study the surface of our natural satellite with binoculars. The best time to do this is actually not on the night of the full moon itself, as it can be too bright. Instead, pick a night a few days before or after the full moon to see the most detail. The easiest features to spot are the Moon's craters – especially the younger ones, which tend to be brighter. You should be able to see a large, bright crater just to the left of the centre of the Moon's surface. This is Copernicus, which is 93km wide and thought to be around 800 million years old (relatively young by the Moon's standards). If you imagine a line of symmetry drawn vertically through the Moon's disk, the Apollo 11 landing site, in the Sea of Tranquillity, is pretty much where Copernicus would be reflected on the other side.

You should also be able to see two more distinctive craters with your binoculars – Aristarchus, which is to the left of Copernicus, and the huge Tycho crater at the very bottom. If you look closely enough you'll see there are many more craters, each one evidence of the Moon's billions of years of meteorite bombardment. ***AB***

LAURIE GUARD (AGE 13), RUGBY

IS THERE A FOURTH DIMENSION?

We're familiar with three dimensions, where just three numbers are enough to pin down our location: longitude, latitude and altitude. We're also surrounded by three-dimensional objects that we describe using length, breadth and height. For thousands of years, the existence of a fourth dimension was dismissed as ridiculous. After all, what would it describe?

But in the mid-18th Century, the French mathematician Jean le Rond d'Alembert pointed out that the fourth dimension could be time. This suggestion was only taken seriously in the 20th Century, when Albert Einstein put forward a new description of the Universe based not simply on location, but on events, each described by four numbers: three for where they occur, and one for when. Thinking of the Universe as four-dimensional 'space-time' proved incredibly powerful, and led to a host of insights about how the Universe and the forces at work in it. For example, according to Einstein, gravity is best understood as being the result of the warping of space-time by matter.

Such insights have led theorists to investigate the idea of more dimensions – in some theories, as many as six extra dimensions, somehow crumpled up too small to observe directly. If true, these theories suggest that hints of the extra dimensions might reveal themselves as new subatomic particles at the Large Hadron Collider. To date, however, there's no sign of them. ***RM***

NASA X4, GETTY IMAGES ILLUSTRATION: DANIEL BRIGHT

10

The number of baby Siamese crocodiles spotted in Cambodia – the species was long thought to be extinct in the wild.

RACHEL CAMPBELL, VIA EMAIL

WHY DOES BOLOGNESE SAUCE STAIN MY PLASTIC CONTAINERS?

The culprit for those stains is a bright red pigment in tomatoes called lycopene. This molecule is 'hydrophobic' (it repels water), and so are your plastic containers. Hydrophobic molecules come together in order to minimise their contact with water, so the pigment clings to the containers. The hydrophobic nature of lycopene also means that it resists attempts to clean it with soapy water, and the high temperatures in a dishwasher can drive stains even deeper into your plastic containers. Try spraying the inside of your container with oil before use, which may help to protect the plastic by giving lycopene something else to cling to. Otherwise, reach for the bleach. ***ED***

EXISTENTIAL FEAR OF THE MONTH...

SCREENS ARE GOING TO SEND ME BLIND

Many of us spend large chunks of our lives staring at computer screens, smartphones and tablets. Long periods of screen time can cause headaches, eyestrain and blurred vision – all symptoms of a condition that's been termed 'computer vision syndrome'. This is caused by our eyes having to constantly work to keep focused over the short distance to the screen. We also blink three times less frequently when using a screen – just 5 times a minute – which makes our eyes dry and itchy.

However, studies have so far failed to find any link between screen use and long-term eye health conditions, such as short-sightedness or cataracts. One 20-year study at the Ohio State University found that children who spent long periods in front of a computer screen or television were not any more likely to need glasses later in life. However, spending at least 14 hours a week playing outside *has* been shown to reduce the chances of becoming shortsighted later. This may be because brighter outdoor light levels stimulate the release of dopamine, which slows the growth of the eyeball and makes it less likely to become distorted later in life. Once you reach adulthood, the best you can do to reduce eye fatigue is take a break from the screen every 20 minutes to gaze out of the window for 20 seconds. ***LV***

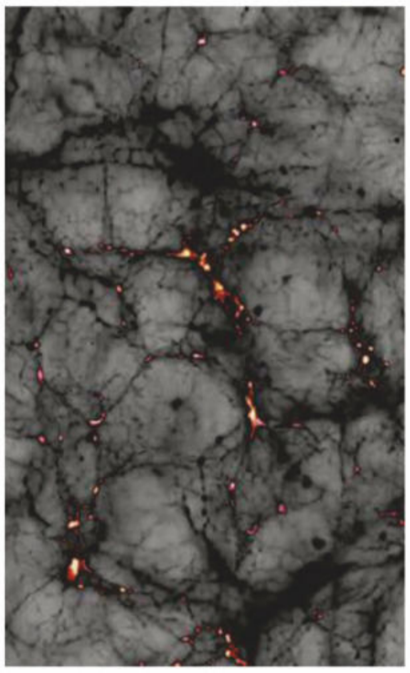
1,300

The length of time, in years, that Lego can survive in a marine environment.

ADAM KING, HUDDERSFIELD

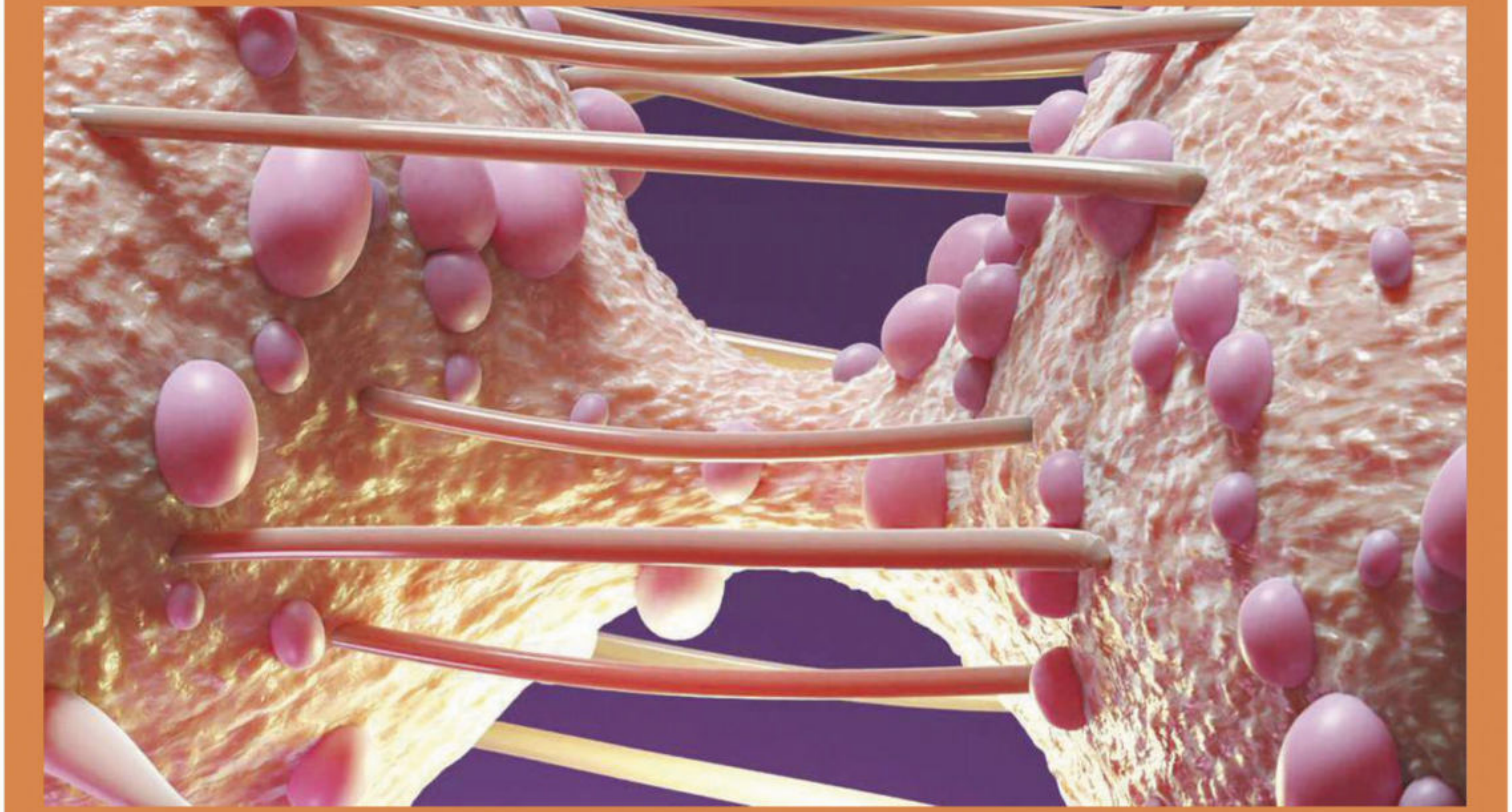
WHAT'S THE MOST ABUNDANT PARTICLE IN THE UNIVERSE?

Measurements of the heat left over from the Big Bang suggest there are about 10^{90} photons in the Universe – making them around 10 billion times more abundant even than hydrogen atoms. But while photons are the most numerous *known* particle, the Universe also contains so-called 'dark matter', whose composition is a mystery. One possibility is that it's made up of particles called axions, whose mass may be so low that they could only account for dark matter by existing in larger numbers even than photons. ***RM***



CROWDSCIENCE

We've joined forces with the team behind BBC World Service's *CrowdScience* to answer your questions on one specific topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **www.bbcworldservice.com/crowdscience**



WHAT IS CANCER?

HAS CANCER ALWAYS BEEN AROUND?

There's a type of medical archaeology, called palaeo-oncology, which searches through our historical records for signs of cancer. Possibly the earliest reference comes from the Ancient Egyptian physician Imhotep, who lived around 2600 BC. He wrote about "bulging masses on [the] breast". Even further back, evidence of cancer has been found in the foot bone of an ancient human relative who lived in what is now South Africa, 1.7 million years ago. So cancer is not a modern disease. But there are times in our history when the disease is not mentioned in the records. It's possible that in ages where populations were ravaged by war, plagues and other infections, death rates were so high that cancer, often an age-related disease, was scarce.

HOW DOES CANCER START?

Almost all the cells in our body need to divide: it's how we grow, and how we repair damaged tissue and worn-out cells. To do this, the cell's DNA makes a copy of itself, and mistakes can happen in this process. These 'mutations' are common, and our body can repair them. But rarely, the mutations take place in a part of the DNA that controls cell division, and the cells don't stop dividing. These cancer cells can eventually form a tumour, and the cancer can spread to other parts of our body.

CAN WE BEAT IT?

One of the most promising areas is immunotherapy, which harnesses the patient's own immune system to fight the cancer. A study published in February this year used engineered bacteria to find and enter tumours, where the bacteria could deliver drugs that help the immune system to recognise and attack cancer cells.

Early diagnosis is also important. The sooner you catch a cancer, the less chance it has to evolve into something more difficult to treat. Another study published in February revealed the complete DNA sequences (genomes) of over 2,600 tumours, helping to pin down the different combinations of DNA mutations that can lead to cancer. It's hoped that this research could help doctors to find and treat cancer much earlier in its development – perhaps even preventing it before it starts.

Marnie Chesterton is a presenter on *CrowdScience*

GETTY IMAGES X12 ILLUSTRATION: DANIEL BRIGHT

YASMIN HAYES (AGE 13), LONDON

IS IT BAD TO WEAR SOCKS IN BED?

No – in fact, it may give you a better night's sleep. A 2007 study at the Netherlands Institute for Neuroscience found that people who wore socks in bed fell asleep faster than those without. The reason is that warming your feet tricks your body into thinking it's too hot, and so it increases blood flow to the skin. This causes your core temperature to drop slightly, and a reduced core temperature is one of the signals that tell the brain to prepare for sleep. It's a good idea to wear a different pair from your daytime socks, though, just to keep things feeling fresh. ***LV***

QUESTION OF THE MONTH

WINNER

Peter wins a Nokia 7.2 smartphone. It boasts a 48-hour battery life, 64GB internal storage, triple camera setup and Full HD display.
nokia.com

PETER SPICER, GLOUCESTERSHIRE

WHY IS POO ALWAYS BROWN, NO MATTER WHAT WE EAT?

By the time it has been through your intestines, most of the natural pigments in food have been digested away (the red from beetroot being a notable exception). The brown colour is due to a chain of processes, which begins with the breakdown of old red blood cells to produce a chemical called bilirubin. This ends up in the liver, where it mixes with bile. The bile travels into the gut, where bacteria metabolise the bilirubin into another chemical called stercobilin, which is brown. ***LV***

TOP 10

HEART RATES

SOME OF THE SLOWEST AND FASTEST HEART RATES IN BEATS PER MINUTE (BPM)

1 Saltwater crocodile
Heart rate: 1-3bpm when underwater
Range: India, Asia, Australia

2 Blue whale
Heart rate: 2bpm when diving
Range: Worldwide

3 Hibernating groundhog
Heart rate: 5bpm
Range: US, Canada

4 Giant tortoise
Heart rate: 6-10bpm
Range: Galápagos Islands

5 Elephant
Heart rate: 30bpm
Range: Africa, Asia

6 Human
Heart rate: 60-100bpm
Range: Worldwide

7 Cat
Heart rate: 140-220bpm
Range: Worldwide

8 Canary
Heart rate: 1,000bpm
Range: Worldwide

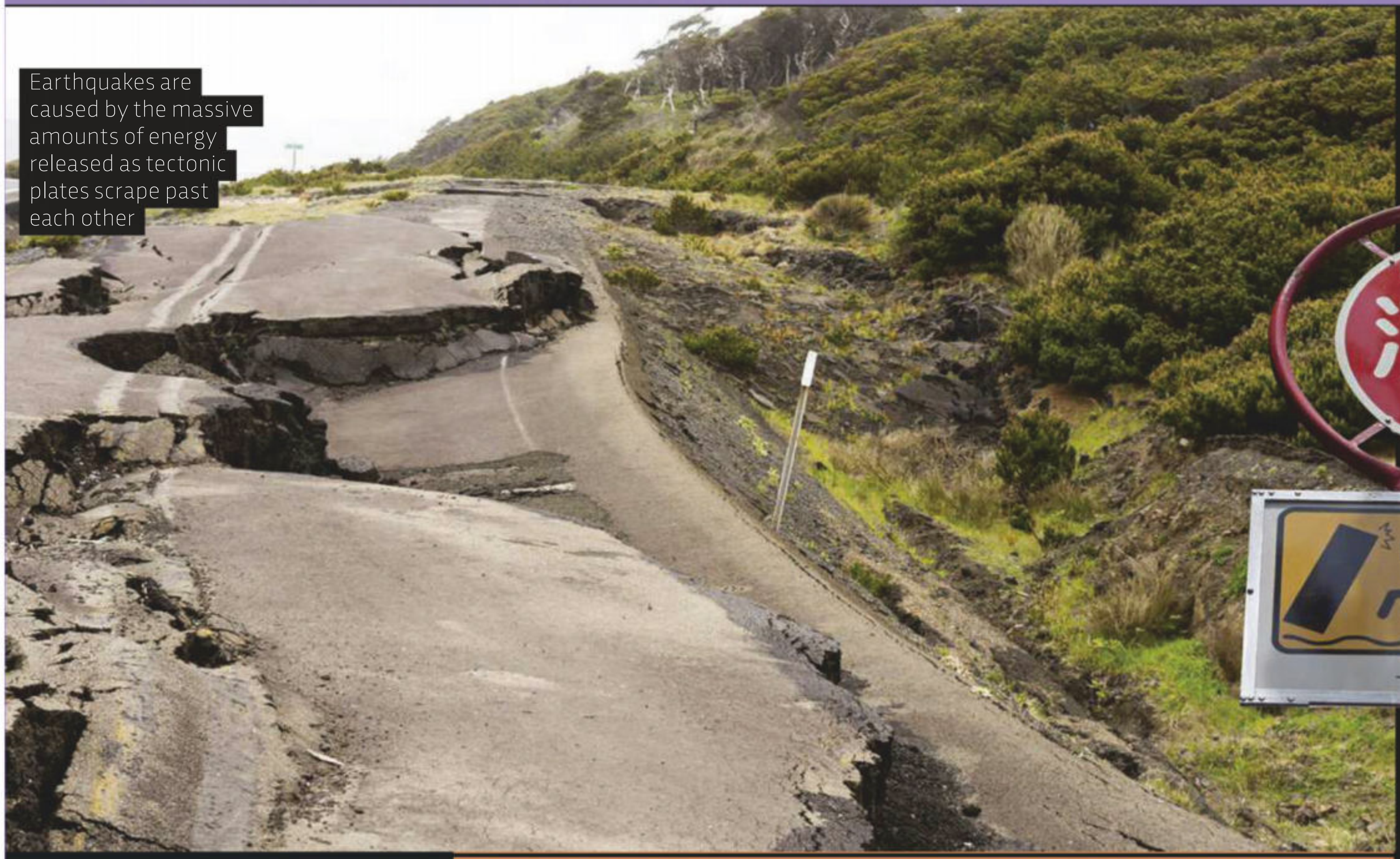
9 Blue-throated hummingbird
Heart rate: 1,260bpm
Range: US, Mexico

10 Pygmy shrew
Heart rate: 1,511bpm
Range: Northern Eurasia

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

THE EXPLAINER

WHY CAN'T WE PREDICT EARTHQUAKES?



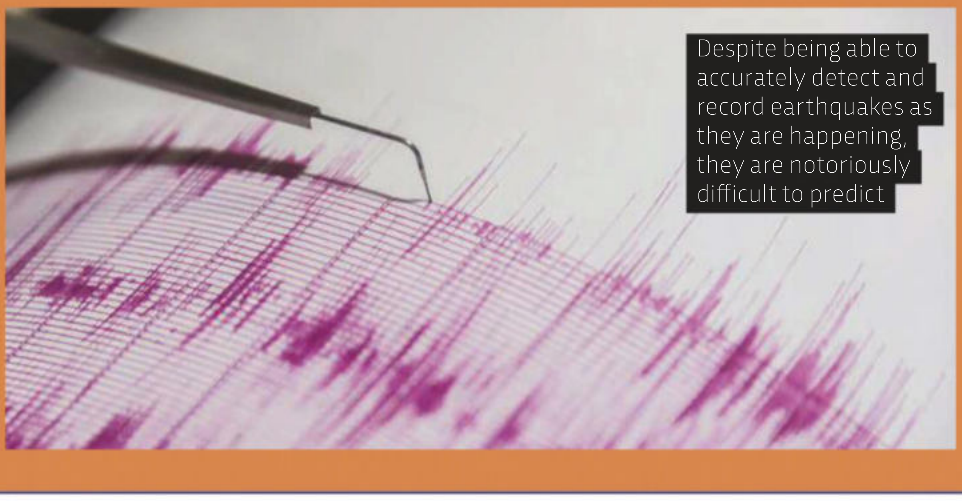
Earthquakes are caused by the massive amounts of energy released as tectonic plates scrape past each other

WHAT CAUSES AN EARTHQUAKE?

As the Earth's tectonic plates push and pull each other, they generate strain that accumulates on lines of weakness in the crust known as faults. When this strain reaches a critical level, a fault will break and the rock masses on either side scrape past one another, releasing a huge amount of energy that causes the ground to shake. Every year, there are more than three million earthquakes; California alone experiences more than 10,000. Most are too small to detect, except by seismometers, but around 15 a year are major shocks of magnitude seven and above, capable of causing major damage and loss of life.

WHY ARE EARTHQUAKES SO DIFFICULT TO PREDICT?

The problem with earthquakes is that – unlike volcanic blasts – they typically happen without consistent warning signs. In the 1980s, seismologists constructed what was touted as the world's most detailed and sophisticated network of monitoring sensors, around the Parkfield segment of California's San Andreas Fault. An earthquake was expected to happen, they had calculated, sometime between 1988 and 1993, and the sensors were designed to pick up precursory physical changes in the crust that could form the basis of an earthquake prediction model. In the end, the magnitude 6.0 quake arrived late, in 2004, with no forewarning or physical precursors whatsoever.



Despite being able to accurately detect and record earthquakes as they are happening, they are notoriously difficult to predict

HOW CLOSE CAN WE GET?

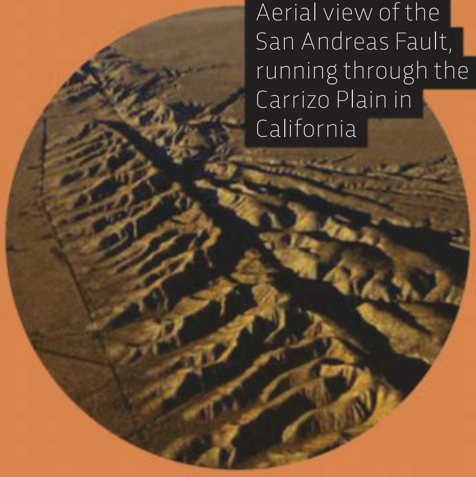
FIRE HYDRANT
消火栓
地震から
命を守る
家具転対策
一 東京消防庁 一

To qualify as a success, an earthquake prediction would have to provide data on the timing, size and location of an event, sufficiently in advance so that action could be taken to limit injury and loss of life. This has never been accomplished. However, earthquakes on most faults have characteristic return periods, so that on one fault they may happen every decade; on another, every century; and so on. The frequency depends upon how much strain a fault can accommodate before it ruptures. This relationship means that earthquakes can be 'forecast'. Forecasts are less precise than predictions but are useful in evaluating the level of risk. So, if there has been no quake for 120 years on a fault that breaks, on average, every 100 years, then there is a high probability that a quake is imminent.

GETTY IMAGES X3, ALAMY, SUPERSTOCK, NASA/JPL

ARE THERE ANY ADVANCES IN THE PIPELINE?

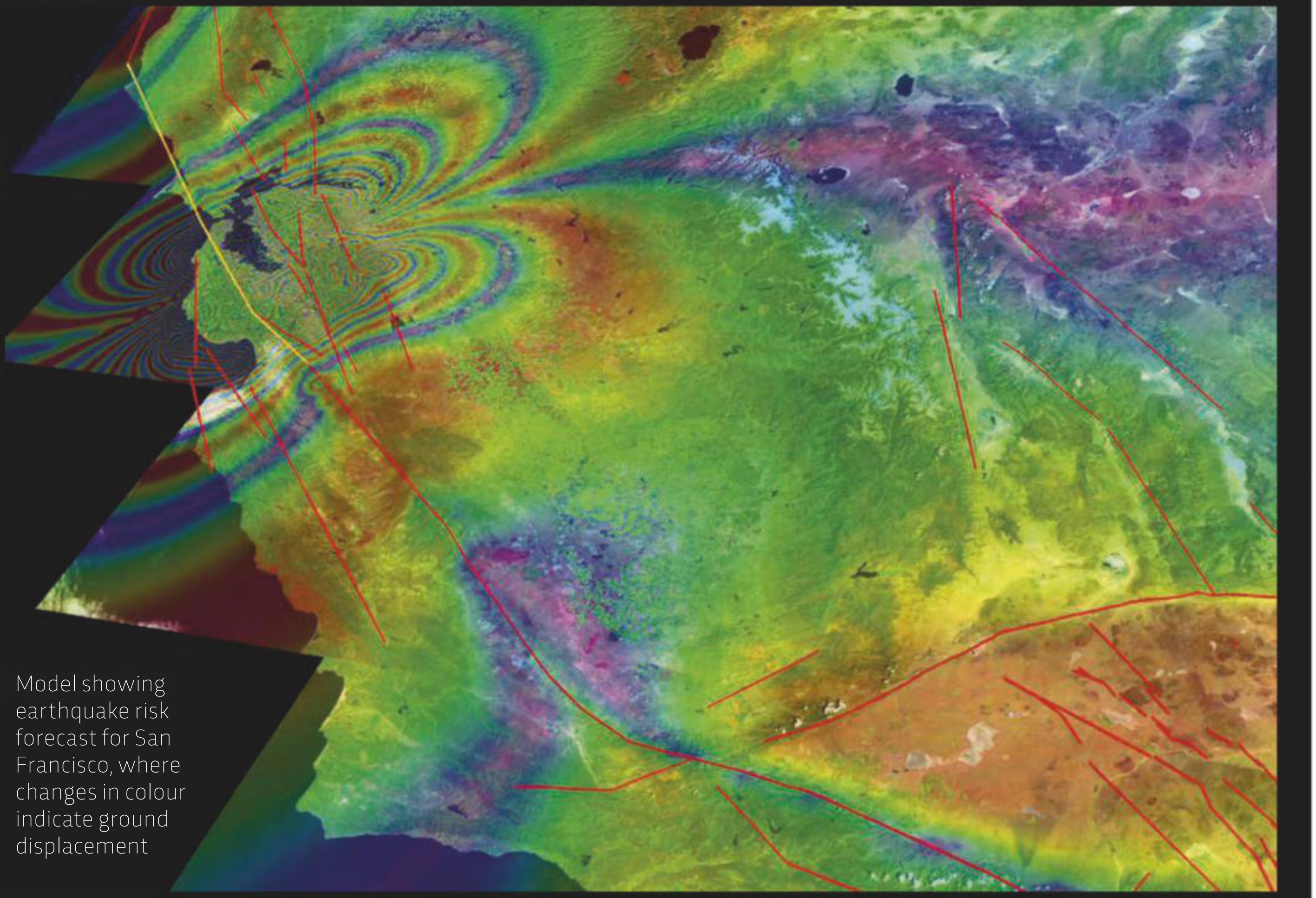
The ability to predict earthquakes has been claimed for all sorts of things, from odd animal behaviour and changes in rock properties, to electromagnetic signals in the crust, and so-called 'earthquake lights' – electrical discharges that have been observed in the sky before some earthquakes. None have proved to be up to the job. But there may be light on the horizon. Scientists monitoring the Cascadia Fault, off the west coast of the US and Canada, have given a machine-learning algorithm their data, with the hope that it can find patterns in the seismic record that could help predict the fault's next big quake.



Aerial view of the San Andreas Fault, running through the Carrizo Plain in California

WILL WE EVER BE ABLE TO PREDICT EARTHQUAKES?

Some seismologists consider true earthquake prediction to be intrinsically impossible because the Earth's crust is in a state of so-called 'self-organised criticality'. If this is the case, it would mean that any tremor – however small – has some probability of ballooning into a major shock. Others argue that prediction is difficult, but we will eventually find a way. If prediction is ever to have any use at all, however, it will have to be accurate, and it will have to be right every time. False alarms would lead to widespread public anger and disillusionment, and they could also mean that people ignore the correct call when it comes, leading to unnecessary deaths.



Model showing earthquake risk forecast for San Francisco, where changes in colour indicate ground displacement

San Francisco lies on a system of significant fault zones, including the San Andreas Fault, meaning there is a high risk of earthquakes

WOULD ACCURATE PREDICTION BE A GOOD THING, ANYWAY?

What if we knew that a large magnitude earthquake was going to strike a major city – say San Francisco – in exactly three months' time? Making such a prediction public would cause widespread panic and a mass exodus from the city. Businesses would close and shift their stock out – many perhaps for good. Shares in local companies would plummet. California state authorities would need to set up camps for the hundreds of thousands fleeing the city, and feed them for months. Much better, say many seismologists and earthquake engineers, is to forget prediction, and focus instead on making buildings 'life-safe'. In other words, construct them well enough so that they don't fall down when a quake strikes, and bring old buildings up to a similar standard (retrofitting). This way, damage is minimised, the death toll is massively reduced, and the economy and infrastructure little affected.

by **PROF BILL MCGUIRE**

Bill is professor emeritus of geophysical and climate hazards at UCL. His novel, Skyseed, *will be published in September.*

BOOKSMART

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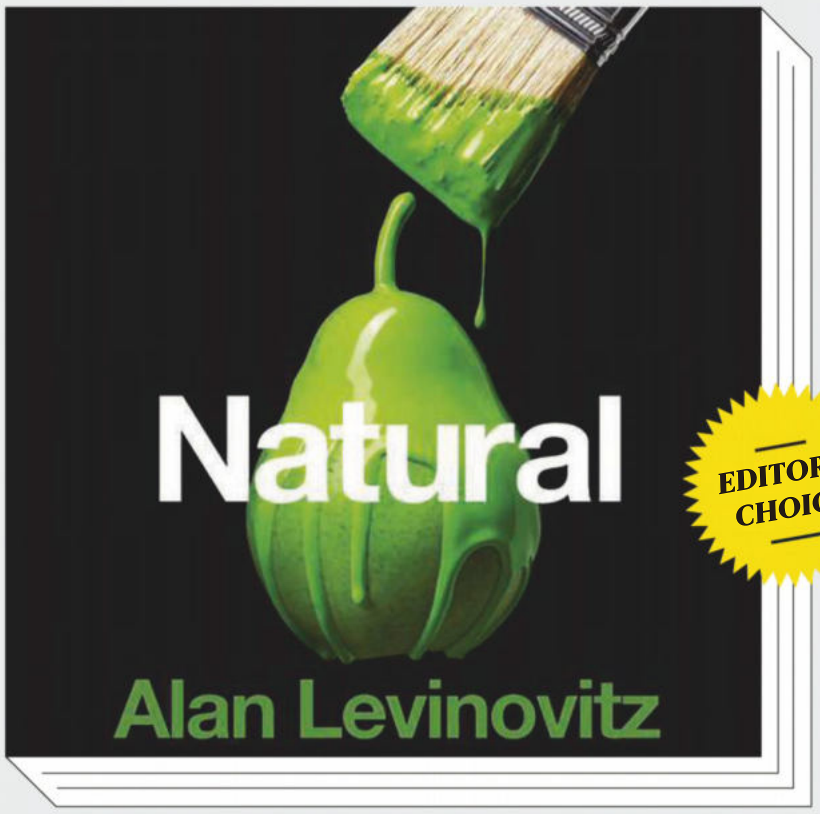
WRITERS' CIRCLE

Authors tell us why their book should be at the top of your reading list this month…



EDITOR'S CHOICE

NATURAL

ALAN LEVINOVITZ
£20, PROFILE BOOKS, OUT NOW

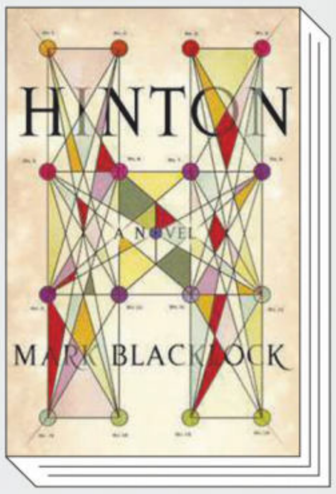
As fears about coronavirus and climate change intensify, it's easy to feel like we are being punished by nature for our unnatural activities. Dense urban centres, an interconnected globe, high population, overconsumption… isn't the problem that we are drifting too far from how nature wants us to live?

But framing our problems, and their solutions, as natural vs unnatural is counterproductive and dangerous, just as it has always been. In *Natural*, readers will see how this approach is religious, not scientific, by substituting nature for God and 'natural' for 'holy'. The anti-vaccination movement, condemnation of unnatural sexuality, deadly pursuit of natural cancer cures, the belief that a race or a gender can be naturally inferior – all are justified by appealing to Mother Nature's commandments.

Now more than ever, we need to live in harmony with the natural world, preserving and protecting it. Yet we must do so without giving in to this disguised fanaticism. Fortunately, it is possible to love nature without worshipping it. On a journey that takes readers from the rainforest to a natural bodybuilding competition, *Natural* shows us the dangers of this religion in disguise, and why we must abandon it.

by ALAN LEVINOVITZ
(@AlanLevinovitz)

A scholar of religion, Alan teaches at James Madison University and has written for Wired, Vox *and others.*



HINTON

MARK BLACKLOCK

£16.99, GRANTA, OUT 2 APRIL 2020

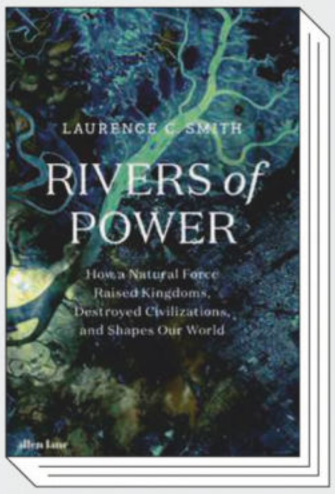
Charles Howard Hinton was a Victorian scientist, inventor and novelist, and an explorer of unmapped realms of the mind. As a young man in the 1880s, Hinton was seized by an idea that had escaped from speculative geometry and been taken up by excitable spiritualists: what if space were four-dimensional, and not limited to length, breadth and height? What if there were another extension, inaccessible to our senses but open to our minds if only we could train them? Just as Hinton's work was gaining readers, scandal struck: he was discovered to have committed bigamy. He was convicted and jailed. Unable to find work on his release, he fled England for Japan and eventually America.

I discovered Hinton's work 10 years ago, and lost myself in unearthing his story. My novel, *Hinton*, recreates his life and invites its readers to become historical detectives solving long-forgotten mysteries and discovering archival crimes.

by **MARK BLACKLOCK**

(@DrBlacklock)

Mark is a novelist and cultural historian, teaching literature at Birkbeck, University of London.



RIVERS OF POWER

LAURENCE C SMITH

£20, ALLEN LANE, OUT 21 APRIL 2020

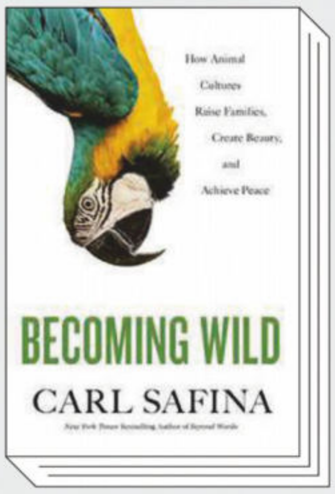
Hiding in plain sight, rivers are a powerful force coursing through the neighbourhoods of two-thirds of the world's population. While the practical benefits of these waterways are obvious, the depth of their hold over us is not.

Rivers define and transcend borders, forcing cooperation between nations. War, politics and urban demographics are jolted by their floods. The territorial claims of nations, their cultural and economic ties to one another, and the migrations of people can be traced back to rivers, river valleys, and the topographic divides they carve upon the world. As water demands, climate change, and disruptive new technologies transform our relationship with rivers, new opportunities are arising to protect the waters and cities that sustain us.

Rivers Of Power reveals the timeless yet under-appreciated relationship between rivers and human civilisation, from the Pharaohs to the modern artificial intelligence era.

by **LAURENCE SMITH**

Laurence has worked on environmental issues with NASA, the UN and the World Economic Forum.



BECOMING WILD

CARL SAFINA

£18.99, ONEWORLD, OUT 9 APR 2020

Throughout the animal kingdom, the genetic tapestry is overlain with more learned culture than humans have realised.

Becoming Wild shows that 'natural' doesn't always come naturally. Many animals learn almost everything from their elders. They get answers to questions of how to live; find out dangers; gain skills, group-identity and communication dialects; and learn traditions that define their existence.

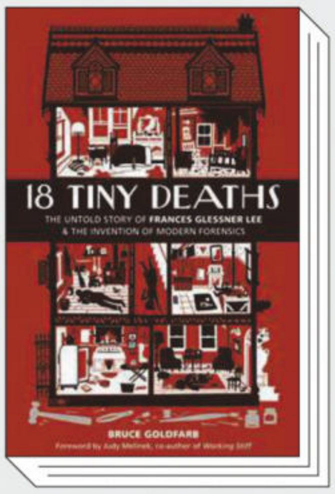
Culture stores information in pools of knowledge that pass through generations. Culture adapts more flexibly and rapidly than gene pools. An individual receives genes only from parents, but can obtain culture from everyone in their group. And because culture improves survival, culture can lead where genes must follow.

The stories of sperm whales, macaws and chimpanzees in *Becoming Wild* represent three major themes of culture: identity, preference for beauty, and how social living creates tensions that culture must soothe.

by **CARL SAFINA**

(@carlsafina)

Carl is a bestselling author, with a PhD in ecology. He is endowed professor for nature and humanity at Stony Brook.



18 TINY DEATHS

BRUCE GOLDFARB

£16.99, ENDEAVOUR, OUT 2 APRIL 2020

Forensic science is one of the leading genres of pop culture, in books, film, TV and podcasting. Everybody seems to love a murder mystery. We've come to expect a CSI-style crime scene investigation, with professionals using the latest scientific technology. But in many parts of the world, that does not happen.

18 Tiny Deaths tells the story of Frances Glessner Lee, who was born in 1878. She was an independently wealthy matron with no academic credentials, yet she was nearly single-handedly responsible for forensic medicine taking root in America. Known mainly as the creator of the exquisitely detailed *Nutshell Studies Of Unexplained Death*, Lee was a reformer, educator and activist. Her life's mission was to move away from the archaic coroner system of death investigation to a modern, scientific medical examiner system. She was commissioned as a captain in the New Hampshire State Police, and earned accolades as the 'mother of forensic science'.

by **BRUCE GOLDFARB**

(@bruce goldfarb)

Bruce is a trained forensic investigator and is executive assistant to the chief medical examiner in Maryland.

INTERVIEW

THE CLIMATE CHOICE

__Christiana Figueres__ and __Tom Rivett-Carnac__ were major figures in the 2015 Paris Climate Agreement. Their book, __The Future We Choose__, reveals that we are on the precipice of two futures: one where net-zero emissions is achieved, and one where it is not…

WHAT WILL IT TAKE?

WHAT WAS THE PARIS CLIMATE AGREEMENT?

TOM: The Paris Agreement was a real breakthrough. For a long time there had been this breakdown in negotiations around the issue of fairness. Developing countries would say to developed countries, "You caused this problem, and what's more, you said you'd sort it out in the early 1990s. So, go away and make real progress, and then we'll talk about a global agreement."

CHRISTIANA: And it is factually true.

TOM: It's a logically consistent argument. And developed countries would say to developing countries, "Well, that's all in the past, but in the future, most of the emissions might come from you, and so we need to do it together." You can defend that from a logical perspective, even though the issue of fairness is clearly still there. So, for years those two sides created a schism in negotiations.

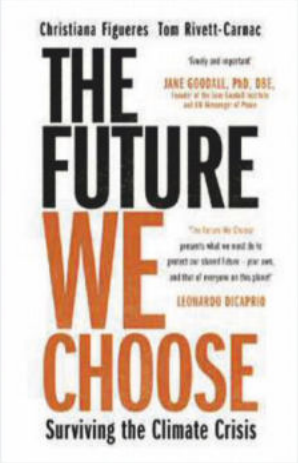
That was ultimately resolved by a two-part agreement: one long-term goal to limit climate change to well under 2°C, and best efforts to 1.5°C, to get to net-zero by 2050. But there had to be successive, nationally determined steps towards that goal.

"That is why the main message in the book is: we have to choose. Both futures are possible now. It's a matter of choice"

YOUR BOOK TURNS TO INDIVIDUAL CHANGE. CAN ONE PERSON'S ACTIONS REALLY MAKE A DIFFERENCE?

TOM: It's a good question. Look at other examples in history, right down to fighting needed conflicts, engaging in great, shared projects. If people said, "If I'm not able to personally solve this massive, systemic, global problem entirely on my own, then I'm not getting out of bed and having a go," it would have been insane.

Our first task is to reduce emissions by at least 50 per cent in 10 years. That's a 7.6 per cent reduction every year, which is unprecedented. It's in excess of anything


Christiana Figueres Tom Rivett-Carnac
THE FUTURE WE CHOOSE
Surviving the Climate Crisis

THE FUTURE WE CHOOSE

£12.99, MANILLA PRESS, OUT NOW

LEFT Extinction Rebellion protesters outside London in January 2020

that humanity's achieved. When you say it to people, they get this tightness in their chest and go, "We're not going to do it! We're not going to make it!"

But the truth is that we overestimate what we can do in a year, and we underestimate what we can do in 10 years. That's enough time to replace the capital-intensive items in your life that are causing most of the emissions. It's even enough time to think, "What do I want to do in the world? Do I want to retrain in some way that can contribute more? How do I change my diet? Do I change my car?"

But it's true that just engaging with our own emissions and footprint won't solve the problem. We also have to engage with power, so, that means raising our voices, pushing corporations to go further and faster, and pushing governments at all levels.

[Christiana and I] completely reject the narrative that we're powerless. We can no longer afford the luxury and the indulgence of feeling powerless.

WHAT DOES THAT PLANET LOOK LIKE IF WE DON'T REACH OUR TARGET OF NET-ZERO BY 2050?

TOM: That's where we start in the book, with an immersive journey to that world. We base it on the science of what the world will look like if we don't make any more efforts to cut emissions. That takes us on the pathway to a world warmed by 3.8°C by the end of the century.

It's entirely possible, with additional decades of burning fossil fuels, that masks will be common. Vector-borne diseases will expand their range, and more people will be subject to West Nile virus, dengue and malaria.

Writing that section of the book was actually a strangely cathartic exercise. Many of us have a dim sense of that world, but bringing it into sharp relief brought me a calm resolve. I was like, "Okay, well now I see it." And I know that I will work the rest of my life to avoid my children living in that world.

THERE ARE TWO CHOICES FOR OUR FUTURE. WHAT IS THE ALTERNATIVE 2050?

CHRISTIANA: That is actually quite an exciting world, the world that we really want our children and grandchildren to live in. It's a world where we have got control over air pollution in cities, so you walk out of your house and the air is moist and fresh. We will have returned fertility to the soil, and life to the oceans. We'll be living in buildings that are producing flowers or vegetables on their rooftop, or they have solar panels, or the sides will be covered in green vines to absorb CO_2.

All buildings will produce their own energy, recycle their own water. Cities will largely produce their own food. We will have far fewer cars. Much less congestion. A lot of the space that is currently dedicated to transit or parking of cars will be dedicated to either charging batteries or, even more exciting, to green spaces.

That's a different world. To say nothing of the fact that many of the low-lying islands currently threatened with disappearing might have a chance of existing.

So, it's a fairer world. It's a healthier world. It's definitely a more stable world, and overall, it's a more prosperous world.

IS THAT WORLD ACHIEVABLE?

TOM: Actually, both worlds are present now, which is what makes this moment in history amazing, right? At a certain point, we will set our path and it will be much more difficult to change it. But at the moment, we stand at the fulcrum between those two worlds. It really is a question of choosing what future we want.

CHRISTIANA: That's what makes the difference. Where do you set your attention? If you set your attention on the pollution and transportation, well then, that's what you see. Whereas if you set your attention on the progress, then you can see evidence of that world. That is why the main message in the book is: we have to choose. Both futures are possible now. It's a matter of choice.

CHRISTIANA FIGUERES

Christiana was executive secretary of the United Nations (UN) Framework Convention on Climate Change. She worked with Tom and others to achieve the Paris Climate Agreement in 2015.

TOM RIVETT CARNAC

Tom was Christiana's political strategist at the UN. Together, they produce the Outrage And Optimism *podcast and have recently published their first book,* The Future We Choose.

GETTY IMAGES

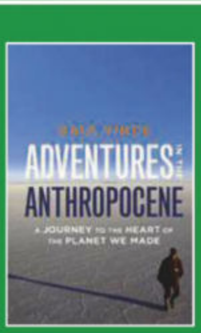
THREE MORE BOOKS ON CLIMATE CHANGE

ON
The (Burning) Case for a
GREEN NEW DEAL
NAOMI KLEIN

ON FIRE: THE BURNING CASE FOR A GREEN NEW DEAL

NAOMI KLEIN
£20,PENGUIN BOOKS

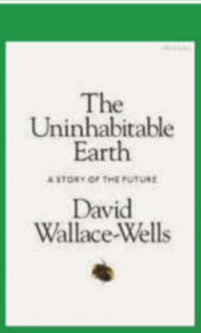
Naomi Klein is an award-winning political author and journalist. Read this to feel confident talking about the climate crisis.


GAIA VINCE
ADVENTURES IN THE ANTHROPOCENE
A JOURNEY TO THE HEART OF THE PLANET WE MADE

ADVENTURES IN THE ANTHROPOCENE

GAIA VINCE
£10.99, VINTAGE PUBLISHING

We have left a mark on the Earth. Journalist Gaia Vince explores our impact on the world, travelling the globe to witness the good, and the bad, in the Age of Man.



THE UNINHABITABLE EARTH

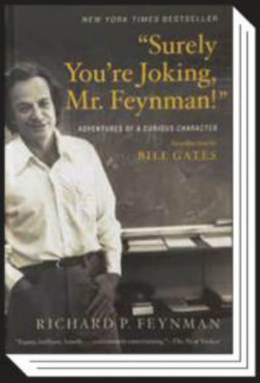
DAVID WALLACE WELLS
£10.99, PENGUIN BOOKS

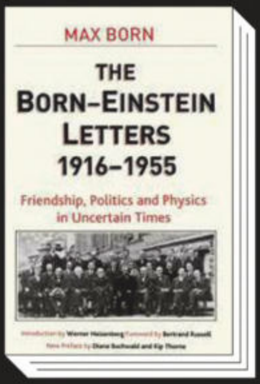
This book is the worst-case scenario of all scenarios, but it is also engaging, inspiring, and absolutely essential reading.

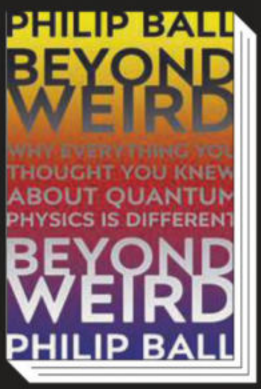
FIVE BOOKS ON... PHYSICS

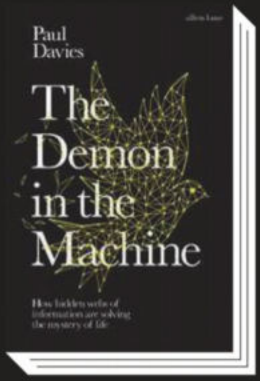
JIM AL-KHALILI

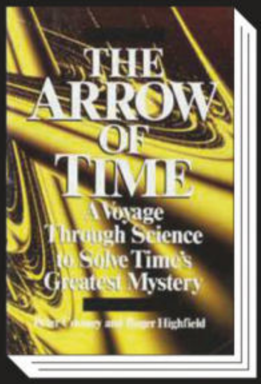
*Jim Al-Khalili is a physicist, science communicator and presenter of **The Life Scientific** on BBC Radio 4. His newest book, **The World According To Physics**, is published in March and documents his self-confessed love affair with the subject. Here, he recommends his favourite books on physics…*


"Surely You're Joking, Mr. Feynman!"
Richard P. Feynman


Max Born
The Born–Einstein Letters 1916–1955
Friendship, Politics and Physics in Uncertain Times


Philip Ball
Beyond Weird
Why everything you thought you knew about quantum physics is different


Paul Davies
The Demon in the Machine


The Arrow of Time
A Voyage Through Science to Solve Time's Greatest Mystery

GETTY IMAGES

1

SURELY YOU'RE JOKING, MR FEYNMAN!

RICHARD FEYNMAN

If you wanted to fall in love with physics, read this book. it's just full of so many gems, about how maverick physicists like Richard Feynman were thinking.

I'm still wrestling with a sort of moral dilemma, I think, as we now look back and re-examine people who were unquestioningly hero-worshipped in the past. In Feynman's private life he was a misogynist, and some of the things he did, there's no way you could countenance these days.

We do need to re-evaluate what Feynman stood for, but I'm still uncomfortable about wiping his achievements from history, or the things that he did that we would not be uncomfortable about.

2

THE BORN–EINSTEIN LETTERS

MAX BORN AND ALBERT EINSTEIN

This book is a compilation of letters between Max Born, who was a German physicist and one of the founders of quantum mechanics, and Albert Einstein.

The pair of them had a long running correspondence, to-ing and fro-ing about ideas on the nature of reality and the nature of physics, which I read and fell in love with as a student.

3

BEYOND WEIRD

PHILIP BALL

This is the book on quantum mechanics that I wish I'd written, but I'm really glad I read. Philip Ball really encapsulates the sheer mystery of quantum mechanics so well.

4

THE DEMON IN THE MACHINE

PAUL DAVIES

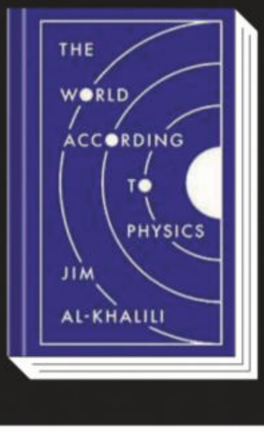
This book is really about whether a physicist can define what life is, and the living systems that are far from equilibrium, yet maintain high-order. For Paul Davies, life is an information processing machine. That's his demon in the machine. It's one of those books where you read a few pages, then you lean back and think and go, "Oh, I hadn't thought of it that way."

5

THE ARROW OF TIME

ROGER HIGHFIELD AND PETER COVENEY

This looks at something profound about the nature of time itself. Why does time go from the past to the future? What is it that gives time a direction? It pulls together lots of different ideas in physics that are still relevant today.


The World According to Physics
Jim Al-Khalili

THE WORLD ACCORDING TO PHYSICS

JIM AL-KHALILI
£12.99, PRINCETON UNIVERSITY PRESS

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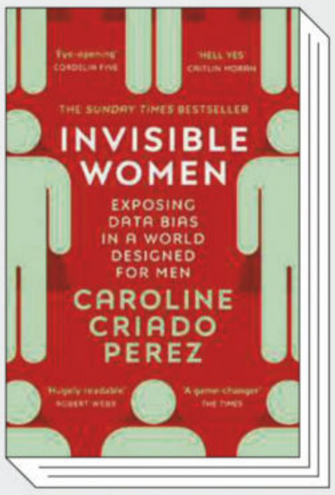
THIS MONTH WE'RE READING...


'Eye-opening' CORDELIA FINE
'HELL YES' CAITLIN MORAN
THE SUNDAY TIMES BESTSELLER
INVISIBLE WOMEN
EXPOSING DATA BIAS IN A WORLD DESIGNED FOR MEN
CAROLINE CRIADO PEREZ
'Hugely readable' ROBERT WEBB
'A game-changer' THE TIMES

Invisible Women

BY CAROLINE CRIADO PEREZ

I've been editing the *Radar* section since July 2019, finding exhibitions, events, festivals and so on to fill your diaries and help you discover great science outside the pages of *BBC Science Focus*. So, it is fortuitous that *Radar* should be replaced by *BookSmart* this month, when many of us are self-isolating or social distancing because of the coronavirus pandemic.

Reading is restful. It has been shown to help us get to sleep, lower our blood pressure and make us feel less stressed. Even the least anxious among us could surely benefit from relaxing with a good book?

The first book we'll be reading won the Royal Society Insight Investment Science Book Prize 2019. It is also a *Sunday Times* bestseller and was winner of the Reader's Choice Books Are My Bag Awards 2019. And those are just a few of its accolades.

In ***Invisible Women***, the reader lives a life where the office thermostat is always set too cold, where you're likely to leave a doctor's appointment with a prescription for a drug completely wrong for your body, and where everything has been designed slightly bigger than one's hand can comfortably hold.

Except, for half of all readers, they're already living that life. We (I mean, women) might not even realise the extent to which the world we're living in has been biased against us, but I assure you, everyone will feel more enraged and empowered after reading the stories of injustice in *Invisible Women*. I'm looking forward to discussing it with you all.

Amy Barrett, *BBC Science Focus* editorial assistant

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Join the Science Focus Book Club in reading Caroline Criado Perez's award-winning non-fiction book *Invisible Women*.

Tweet your review of the book with the hashtag #SFBookClub and we'll print some of our favourites in the next issue.

Stay in touch with other SF Book Clubbers while you're reading using the hashtag #SFBookClub and tweet us your questions about the world of data bias – we'll ask them to Caroline in a special Q&A on 21 April.

GO TO sciencefocus.com/science-book-club TO JOIN THE SCIENCE FOCUS BOOK CLUB AND GET...

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- An exclusive podcast interview with Caroline
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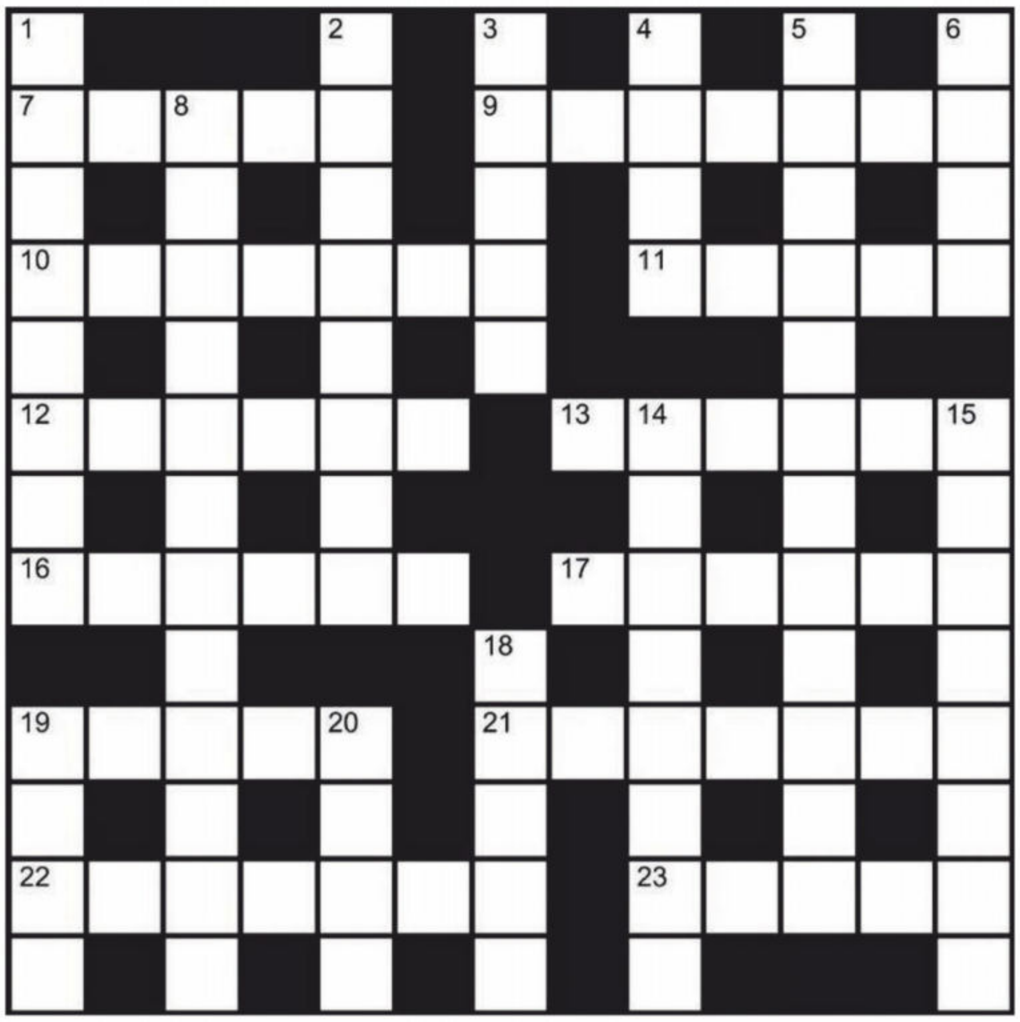
CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 Gold gets Georgia new liver, say (5)
9 French house has spirit (7)
10 See code is cracked by European (7)
11 Request time to fold (5)
12 Bank a rand with other capital (6)
13 Chicken mostly seen carrying weight (6)
16 Professor broke leg on computing device (6)
17 Second Catholic trip organised by text (6)
19 Offer to take exercise like a man (5)
21 Shorten a game (7)
22 Details and directions about current class (7)
23 Boy finds object returning in some rivers (5)

DOWN

1 Come down to club first in forest (8)
2 Basic change to triangle (8)
3 Cat doesn't begin around English church (5)
4 Rear parking shows sign of impending issue (4)
5 Forgetful sailor has broadcast looked after (12)
6 Creature of biting nature (4)
8 Instrument gets locks peeling away (12)
14 Precise notes by cleric (8)
15 Rely on running after flier, being maternal (8)
18 Sculpted a slab in wood (5)
19 Foundation is corrupt (4)
20 Blue back around this third platform (4)

ANSWERS For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

THE SECRET LIVES OF ANCIENT MAMMALS

We know the dinosaurs died out when the asteroid hit. But what were the planet's furrier animals doing back then?

ALAMY

PLUS

FLYING ON MARS

The chopper that will fly on the Red Planet.

LIFE AFTER US

How nature reclaims our abandoned sites.

THE FUNGUS AMONG US

How these incredible organisms will transform our future.

ON SALE 6 MAY

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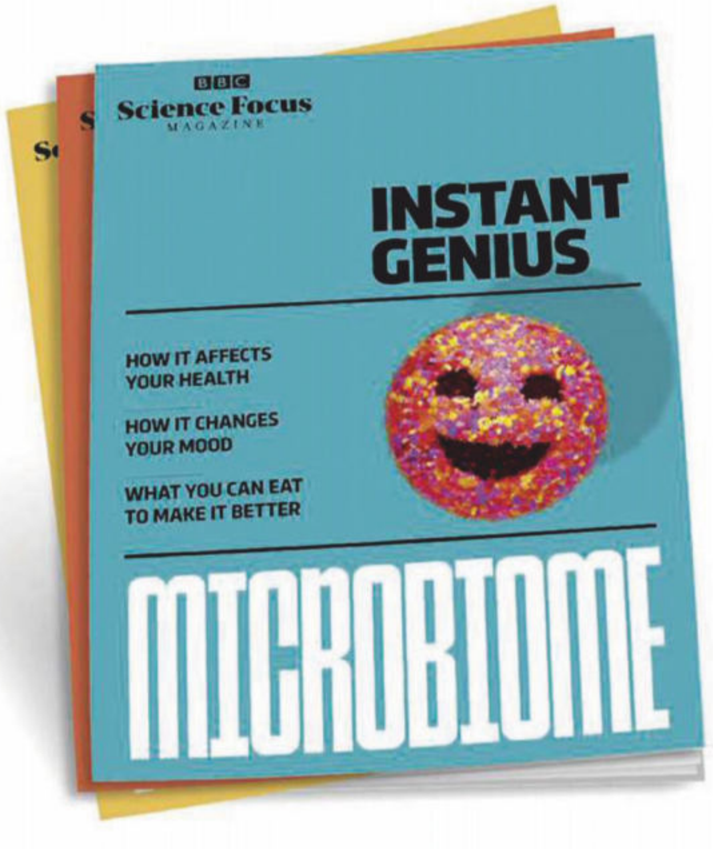
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A SCIENTIST'S GUIDE TO LIFE

HOW TO RUN A LONG, LONG WAY

THE LONDON MARATHON HAS BEEN POSTPONED, BUT EXERCISE IS VITAL RIGHT NOW. HERE'S HOW TO TACKLE A 26.2-MILE RUN, WITH SPORTS SCIENTIST **DAN GORDON**

GET THOSE MILES IN

A current trend is to do high intensity gym training to get fit quickly. That won't help with a marathon. You have to get mileage into your legs because the key to success is having what I call an 'aerobic base'. That doesn't mean you need to cover *vast* distances. For those who are new to marathons, you need to build up to 45km (28 miles) a week on average, with that distance split over several runs.

PLAN A *BIG*(-ISH) RUN

You need to experience a long run before the marathon itself. Less experienced runners tend to do a longest run of about 29km (18 miles). You want to do that about three to four weeks before the marathon. If you are new to the marathon, you don't want to be doing that a lot because you cause muscle damage, muscle fatigue, pain in the legs and so forth.

INCREASING THE 'MILES PER GALLON' OF YOUR BODY IS KEY

You want to be able to use less energy per footfall. As you train, you get more capillaries in the muscles to get oxygenated blood to them. Your heart gets bigger on the outside, and the cavities inside – the ventricles – also enlarge. So per beat, the heart can eject more blood. You get increased levels of aerobic enzymes and increased mitochondria, where aerobic metabolism takes place.

PLAN FASTER RUNS INTO YOUR WEEKLY TRAINING

We're talking about the kind of running where you can't quite hold a conversation. You could run in the 'tempo zone', as we call it, for 40 minutes non-stop, which is pretty hard. Or you could do it in 10-minute blocks with a short recovery in between.

EAT THOSE CARBS TO HELP YOU PREPARE

The big fuel for your body is carbohydrate. It also helps during recovery. You need to ensure your diet is carb-rich, with plenty of foods like pasta, and bananas to help recovery. You are causing muscle damage when you run, so you need protein to help with muscle repair – things like chicken, fish and pulses. If you refuel your body within about 60 minutes of stopping your run, you get metabolic recovery and all the fuels are restored within 12 to 14 hours. Leave it longer than an hour and you're looking at anything up to 72 hours for recovery.

ON MARATHON DAY, EAT WHAT YOU CAN KEEP DOWN

Things like muesli or porridge with fruit are good as they release the energy slowly. If you eat fast-energy-release foods you get an instant hit, but you might run out of energy.

PACE YOURSELF TO AVOID PAIN

The two biggest causes of pain in a marathon are when you lack preparation – you've not run enough miles in training – and poor pacing in the marathon itself. The former results in just having to run slowly throughout. The latter leads to pain. Most runners go too fast at the start of the marathon and will burn energy too quickly. This will lead to them running out of energy too soon and having to slow down. It then becomes an uncomfortable run. SF

DAN GORDON
is principal lecturer in exercise physiology at Anglia Ruskin University. He was consultant physiologist to the UK Athletics Paralympic Team 2003-2008.
Interviewed by Andy Ridgway.

NEED TO KNOW...

1

Don't run distances that are too long in training.

2

Training increases the number of capillaries in your muscles and makes your heart larger.

3

Refuel your body with food within 60 minutes of a training session to speed up recovery.

ILLUSTRATION: CATHAL DUANE

Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk
or visit stroke.org.uk/legacy

Stroke association

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Illustration by Lauren Rolwing